Volume 31 JULY, 1947 Number 7

BULLETIN
of the
American Association *of* Petroleum Geologists

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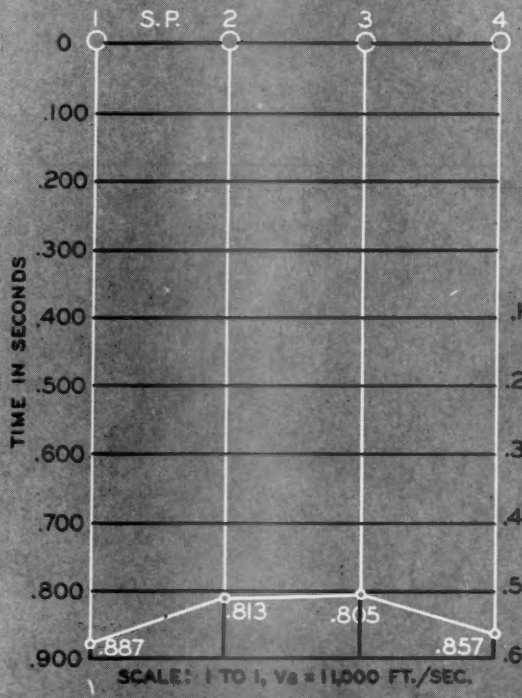
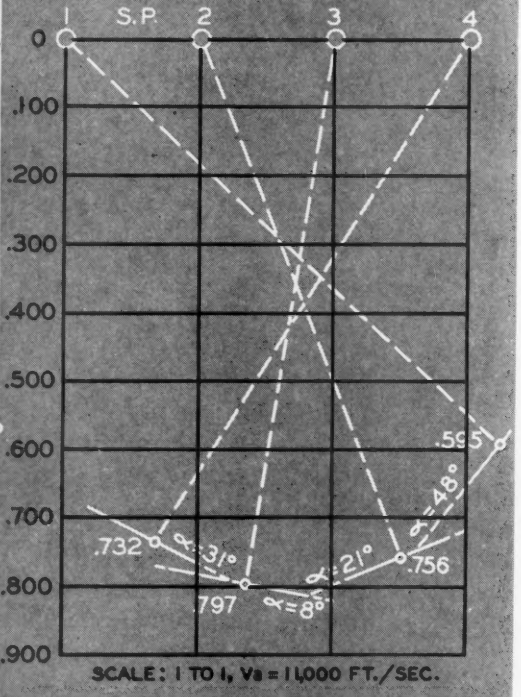
Steep Dip Shooting



Undisplaced data plotted as if originating vertically below surface recording points. Note apparent anticline. (Above)

Displaced data from same records plotted at calculated sources of reflections along the line of profile. Note true structural attitude is synclinal. (Right)

Steep Dip Shooting requires an appreciation of the lateral migration of the reflecting points relative to surface control. Failure to properly evaluate this factor may result in erroneous interpretations.



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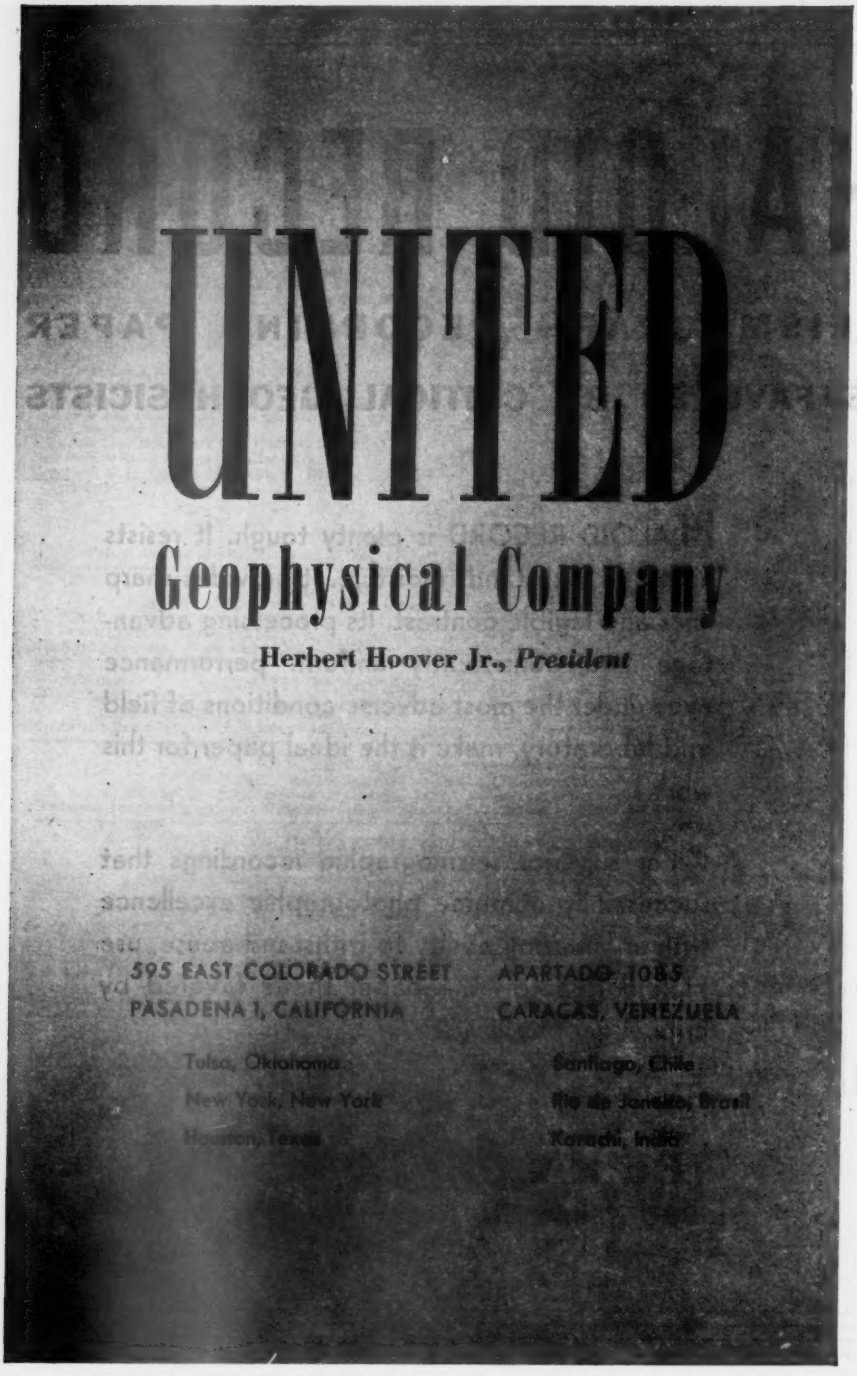
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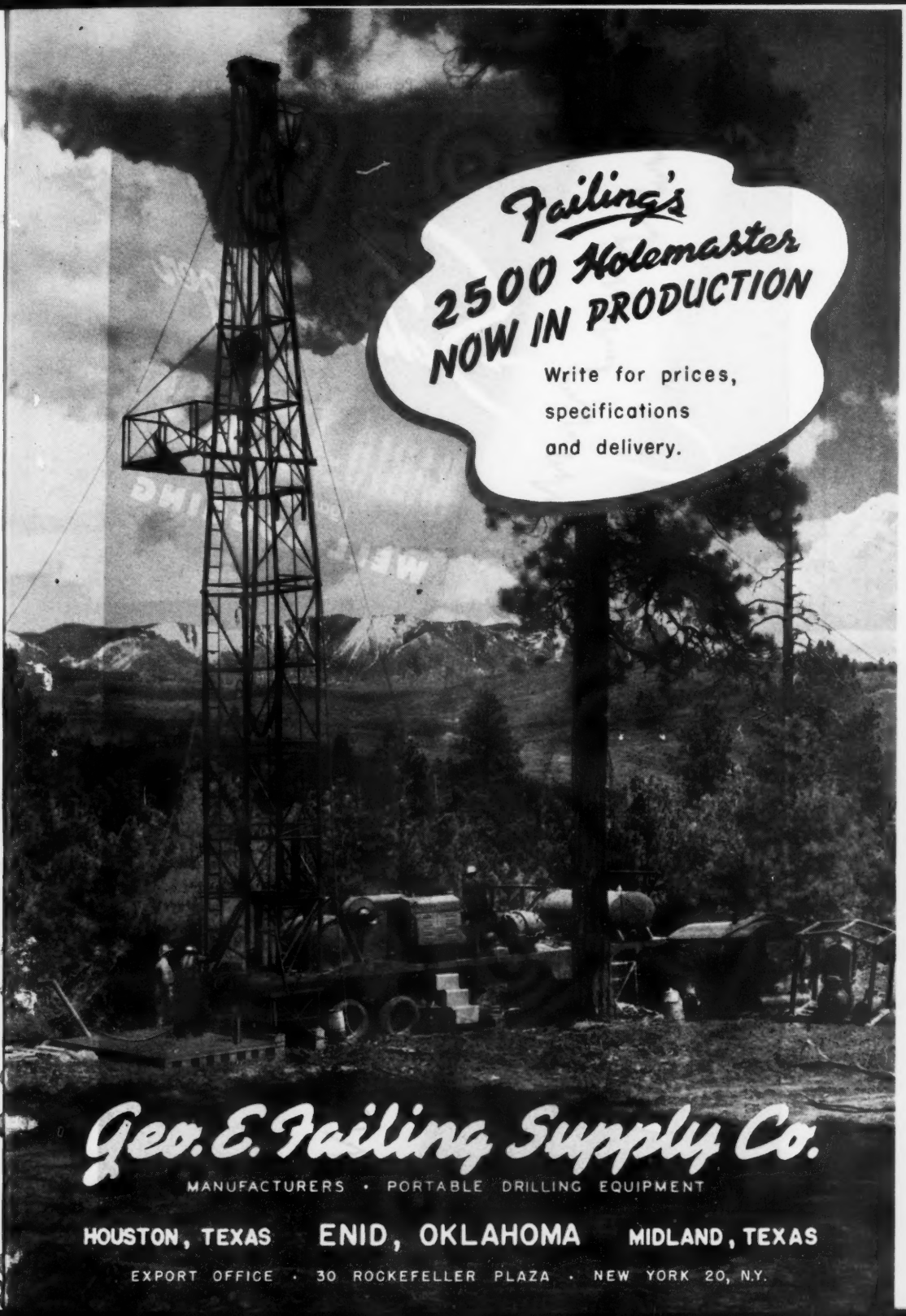
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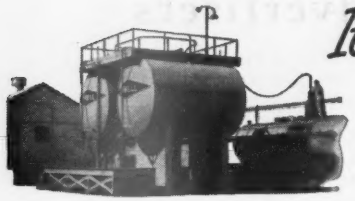

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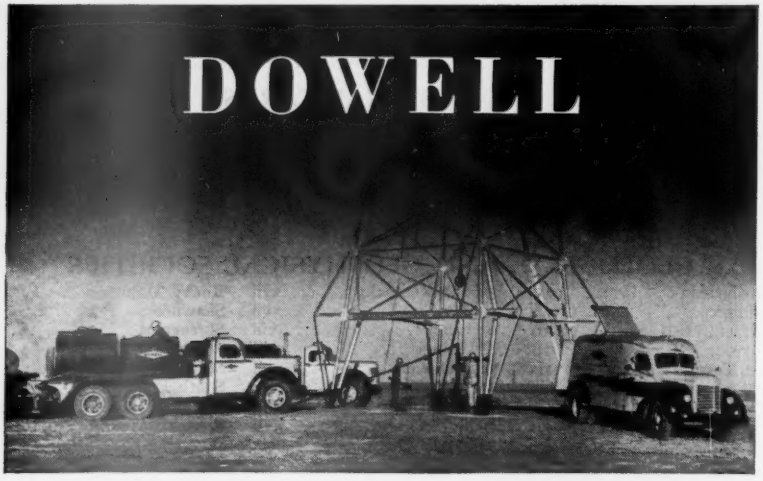

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Volume 31 Number 7

BULLETIN
of the
AMERICAN ASSOCIATION OF PETROLEUM GEOLOGISTS

JULY, 1947

GEOLOGICAL MASKS AND PREJUDICES[1]

EARL B. NOBLE[2]
Los Angeles, California

INTRODUCTION

As scientists we are interested in new developments which may have future significance for us. The discovery of new lands in Antarctica and the presence of a shallow submerged shelf in the Arctic regions suggest potential new stores of natural resources. The apparent shifting of the north magnetic pole 200 miles in the last 50 years may indicate important readjustments within the heavier constituents of the earth's interior. The extreme variations in high-altitude temperatures recorded in the V-2 rocket experiments may alter our concepts of conditions responsible for some of the great climatic changes of the past. And the substantial progress that has been made in nuclear physics and atomic research may indicate a slow but gradual transition from oil, coal, and other synthetics to radioactive or fission materials as sources of heat and power.

As petroleum geologists we are more vitally concerned with the immediate problems of the petroleum industry. Can production be maintained—can recovery be increased—can we find sufficient new supplies of oil to maintain our present reserve position?

The American oil industry has experienced rapid world-wide expansion, much of which has taken place since last we met in Los Angeles. It is interesting to note that some 23 billion barrels, or almost half of all the oil produced by man since the beginning of time, has been produced in this 10-year period. In this same interval the United States has produced 45 per cent of its cumulative past production; Texas has produced 56 per cent and California 36 per cent.

Our domestic reserves of crude oil have increased from an estimated 13 billion barrels in 1936 to 21 billion barrels in 1946, a net gain of 8 billion barrels, or 38 per cent. If we add to these reserves the recent estimate of 3 billion barrels of

[1] Presidential address, 32d annual meeting, Los Angeles, March 25, 1947.

[2] Manager of exploration, Union Oil Company of California.

natural-gas liquids, we now have an estimated total proved reserve of more than 24 billion barrels of liquid hydrocarbons and 160 trillion cubic feet of natural gas. During this same period yearly production has grown from a billion barrels to 1¾ billion barrels, an increase of 75 per cent. This means that we must add almost 2 billion barrels of new oil each year to maintain our present reserves.

We are drilling twice as many wells now as we did in 1936 in search for new oil; and drilling them deeper. All but one of the 326 wells[3] that have gone below 12,000 feet have been drilled in this same 10-year period; and one has already passed the 17,000-foot mark.

Increase in exploratory activity is reflected in A.A.P.G. membership which has more than doubled since 1936. The general trend in exploration is indicated by the great number of our members now resident in foreign countries.

Ten years ago we were in the early stages of a high oil-finding period, largely made possible by the introduction of the reflection seismograph which enabled us to locate structural features in the alluvium-covered valleys and coastal plains. The present outlook for finding adequate new supplies of oil is not as promising as it was at that time, except in the still green pastures of foreign countries.

Much of our future supply of oil will be found by close teamwork between various oil-finding groups, utilizing all of our present known prospecting tools and exploration methods. To a great extent this effort will consist of detailed subsurface studies in the search for stratigraphic traps and accumulations on the flanks and extensions of known structures; and drilling deeper wherever possible. There are, however, some rather extensive areas having good oil possibilities but about which we know very little because of a cover which masks the underlying geological conditions and which we can not effectively penetrate with any of our present methods because of physical or economic considerations.

MASKS

Sediments under the over-riding cover of older rocks in zones of low-angle thrust faulting and those hidden under a thick mantle of younger volcanics may have good oil possibilities where the structural conditions and stratigraphic facies of the foreland are known to be favorable. High-velocity limestones are at the surface over extensive areas where additional oil fields should be present. Thick deposits of drifted sand, till, and loess act as an obscuring cover, and multiple unconformities effectively hide underlying structure through their own structural complexity. Even the water over favorable portions of the continental shelf can be considered as a mask. Its removal in the Gulf Coast district would leave a featureless bottom surface which would have to be explored by geophysical methods, but many of the oil fields that undoubtedly exist off the coast of Southern California might easily be found by surface geology alone if the water cover were removed.

[3] Ernestine Adams, "Deep Exploratory Wells on Increase," *Petroleum Engineer* (February, 1947), p. 51.

Along some of the major zones of thrust faulting, oil may be found in the overthrust sheet associated with asymmetric anticlinal folding, as at Turner Valley in western Alberta, but it may also occur under simple or complex structural conditions beneath thrust sheets as at Jumping Pound in the Alberta foothills or the Aliso Canyon field in Los Angeles County, California. In northwestern Montana alone, it is estimated that 4,000 square miles of younger sediments having a favorable facies are over-ridden and obscured by older rocks of the Lewis overthrust. In addition to this there is a disturbed belt 30 miles wide in front of the thrust fault, in which confused structural conditions of the younger surface beds mask geological conditions in the underlying Madison and older formations.

Somewhat similar conditions exist in southwestern Wyoming and southeastern Idaho on the east front of the Wyoming Range in the Darby, Absaroka, and Bannock lines of overthrusting where conditions in the foreland suggest a favorable section and low folding under the thrusts.

Mid-Continent geologists have long recognized the possibilities of favorable conditions under the cover of extremely hard older rocks of the Ouachita overthrust in southeastern Oklahoma. Most California geologists believe additional production will some day be found along or under the San Cayetano, Santa Susana, Oak Ridge, or other overthrusts in Ventura County.

Prospecting beneath these overthrust sheets is often a perplexing problem. In many areas geological studies made from surface observations give little or no indication of conditions in the underlying younger sediments; core holes may cost more than $100,000 apiece; and geophysical methods may be generally inapplicable due to rough terrane, high-velocity beds at the surface or complicated structural conditions of the nappe. I hope this subject will be explored further at the Wednesday night symposium when such authorities as Link, Lammers, and Blackstone[4] will discuss overthrusts in greater detail.

Late Tertiary volcanics in northwestern Wyoming varying from a few hundred to several thousand feet in thickness cover an extensive area of Mesozoic and Paleozoic sediments which produce oil in contiguous areas. In some of the deeply cut canyons there are indications of folding in the underlying beds involving horizons which are present on the crestal portions of some of the producing fields in the Big Horn Basin. The Columbia River basalts cover thousands of square miles in Washington and Oregon and effectively mask folded Cretaceous and Tertiary strata. Some of these underlying sediments consist of thick continental deposits which here and there interfinger with marine beds and apparently grade westerly into a thicker marine series. Other areas of interest are in southeastern Idaho where Tertiary volcanics mask Mesozoic and Paleozoic rocks that appear to have structural and stratigraphic conditions capable of producing oil; and in southwest Texas where Tertiary volcanics cover several hundred square miles of Cretaceous and older sediments.

[4] T. A. Link, E. C. H. Lammers, D. L. Blackstone, Jr.

Portions of Nicaragua, Costa Rica, and Panama are covered by late Tertiary and Quaternary volcanics that may mask favorable conditions in marine Tertiary sediments.

A thick series of lavas of probable Triassic age covers an area of more than 1,000,000 square kilometers in the Paraná Basin of southern Brazil. Evidence of some low folding and the presence of some bituminous limestones and tar-impregnated sandstones in the peripheral area suggest the possibility of favorable conditions for oil beneath this thick basaltic cover.

Many geologists feel that additional oil fields will be found in areas where high-velocity limestones are present at or near the surface but where the usual geophysical methods fail to give us a satisfactory picture of the underlying structure. The Edwards Plateau of Texas, southern Florida, and the Yucatan Peninsula of Mexico are good examples of favorable areas masked by relatively flatlying limestones. The seismograph fails to produce satisfactory reflections under these conditions. Geophysicists tell us that either the energy is not transmitted to depth, or the limestone vibrates with a high-frequency ground roll which masks the energy reflected from the beds below. Whatever the reason, it is principally a geophysical problem and undoubtedly will be satisfactorily solved by the geophysicists themselves. Some seem to think secondary refraction is the answer, at least in locating the larger structural features.

Sand dunes, glacial débris, and loess partially mask certain areas having reasonable oil possibilities. However, they present only minor difficulties as a rule, except where they occur in considerable thickness.

Complicated conditions above an unconformity may hinder proper interpretation of structure below the unconformity and so may be considered as one of the minor masks. The solution here lies in having sufficient subsurface control for detail correlation.

The last mask in this list and the most extensive one is that of water. It covers extensive areas of the Continental Shelf that Pratt and others have estimated contains billions of barrels of oil. Water is not in itself a difficult mask to penetrate. The gravity and seismic methods successfully used on shore can readily be adapted to this new environment. The greater cost of development will, however, be an important factor in determining the rate at which these offshore prospects will be drilled.

Gulf Coast operators will undoubtedly proceed cautiously, at first limiting actual drilling to the larger non-piercement type structures within the 10-fathom mark before attempting to prospect features that might not prove profitable under the added costs of water operations.

Millions of barrels of new oil will be found in structures along the relatively narrow shelf off the coast of Southern California when certain legal restrictions are removed. These fields will be located by a combination of underwater observations, submarine sampling devices, and reflection seismograph. Restrictive regulation rather than water has been the deciding factor in retarding offshore exploration in California.

Curiously enough, California had offshore production prior to 1900. Sometime between 1894 and 1899 a number of wells were drilled from wharves offshore in the Summerland area. Some of these wells were drilled as far as 1,230 feet offshore and in 12 feet of water. Since that time production has been obtained in several offshore fields where drilling has been from piers or by slant drilling from onshore locations; and in one case, from a pier-type construction consisting of an island with no direct connection on shore.

PREJUDICES

In reviewing the past we are amazed that certain obvious structures were not drilled sooner, and that areas now known to be favorable were so long overlooked. This may have been due to a lack of imagination or may have been due to prejudice in our thinking at the time.

Prejudice is used here in the sense of premature judgment, based on insufficient evidence, not in the sense of bias or refusal to accept facts.

The tendency of the early operators in San Joaquin Valley to stop at the top of the "brown shale" on the theory that deeper possibilities were limited to irregular and scattered sand lenses delayed the development of the Miocene and deeper formations in the Valley which now yield more than two-thirds of the daily production in this area. The possibility of substantial production from blanket sands below the top of this "brown shale" was not generally accepted until after the Miocene discoveries at Kettleman Hills and North Belridge. The early discovery of Kettleman Hills, long recognized as a closed anticlinal structure, was delayed by opinions widely held at that time that the structure was too big and the sands too thick to be fully saturated; that oil could not exist in liquid form at depths approaching 10,000 feet; and that any sands present at that depth would be too tight to form a suitable reservoir.

Kansas geologists who now recommend drilling to objective formations down to and including the top of the Cambrian will recall when drilling stopped at the top of the Mississippian. Operators drilling on piercement-type domes in the Gulf Coast bottomed their wells near the top of the salt until production was discovered under the overhang at Barbers Hill in 1927.

Every oil district has had a somewhat similar experience. It is only within the last couple of years that the Rocky Mountain operators have accepted the idea of drilling 10,000- to 12,000-foot tests. In view of the large number of deep producing wells to-day, and the industry's ability to drill to depths greater than 17,000 feet, it seems absurd that so many operators should have hesitated to test that part of the sedimentary section that now looks so favorable to us, at least that part of it within the recognized limits of their drilling equipment. Undoubtedly many of these decisions were based on considerations of high initial investment, doubtful reservoir performance, and excessive production costs.

This feeling was prevalent at the time of our last annual meeting in Los Angeles, and influenced drilling on prospects having objective formations below 10,000 feet. The discovery of prolific production at Rio Bravo in Kern County,

California, that same year, proved conclusively that highly profitable production could be obtained from formations below 11,000 feet; and did much to remove the general prejudice against deeper drilling. Production is now obtained down to depths of 13,778 feet.[5]

In general it is good geological reasoning to stop a well when the drill has entered a formation which the preponderance of evidence indicates is basement. Nevertheless, experience in some areas suggests the necessity of very careful consideration to determine whether conditions exist which might have altered the general characteristics of the basement rock locally.

Weathering or faulting may provide or induce porosity in these otherwise dense or tight rocks and accumulation may result from contact with younger oil measures or source beds. Production from the Knoxville of the Santa Maria Valley field and from the schists of the Bakersfield and Los Angeles Basin areas are local examples.

The use of the term "Weber quartzite" in describing the Upper Pennsylvanian sand in the outcropping section in northwestern Colorado undoubtedly played a part in delaying the discovery and retarding the development of deep production at Rangely. In the Mid-Continent the Hunton was generally considered "flashy" before the discovery of excellent production from the Bois d'Arc member of the Hunton at West Edmond.

The Cretaceous of California is rather generally considered as capable of producing gas rather than oil, even though small amounts of oil were produced from the Cretaceous at an early date and seepages are known.

A tight Kansas City section may temporarily condemn an area in western Kansas or eastern Colorado even though the irregular and spotty nature of porosity in limestone is well known.

Areas of thick continental deposits are slow to receive attention, probably because of preconceived notions as to what constitutes source material. Gas is commonly found in continental sediments under conditions that leave no doubt as to its non-marine origin. Surprising amounts of oil have been produced from continental-type sediments, but the origin of the oil has generally been attributed to the proximity of a marine environment.

In several of the fields along the east side of the San Joaquin Valley and in some of the Tertiary sand areas of the Gulf Coast, the presence of oil in beds of non-marine origin can be logically explained by updip migration from areas of marine deposition. Production from the Sespe redbeds of the Santa Clara Valley, California, can be explained by faulting which has brought a favorable marine section against these porous continental beds. Oil from the non-marine Morrison formation of Wilson Creek in northwestern Colorado, the Shinarump conglomerate at Rangely, the Kootenai sands of north-central Montana, and the small

[5] World's deepest production at end of 1946, Shell Oil Company's No. 2 Smith State Unit 1, at Weeks Island, Iberia Parish, Louisiana. Total depth, 14,301 feet. Producing interval 13,763–13,778 feet (Miocene).

amounts of oil from the Permian and Triassic redbeds in a few of the fields in Wyoming probably is derived from marine source rocks.

However, the substantial quantities of oil and gas present in fluvial and lacustrine sediments of lower Eocene age at Hiawatha and Powder Wash in northwestern Colorado occur under geological conditions that strongly suggest nonmarine Tertiary rocks as a source. Production in some of the fields along the east side of the Andes of Argentina and Bolivia comes from a glacial series of Permo-Pennsylvanian age; and at Comodoro Rivadavia in southern Argentina oil is reported to occur in sediments of continental origin. At Bakú and several other fields in the great Caspian Basin oil is present in a brackish-water series.

Curiously enough, when the reflection seismograph was first introduced into California some few felt it might be used to find shallow deposits of gas; but that it probably would not locate deeper structures which might contain oil. Possibly some of the misconceptions about the deeper possibilities of the alluvium-covered portion of the San Joaquin Valley may have been due to an opinion expressed 10 years previously by a prominent geologist to the effect that he had yet to see a place in California where structure was not reflected in some manner at the surface and that since these structures had been largely tested he looked for few, if any, more large fields in the state. In spite of its success in several areas in other states, the reflection seismograph was not generally accepted in California until after the discovery of Ten Section field.

Not all of our prejudices are ancient ones, nor are they necessarily all on the negative side. The very fact that we realize we have had them tends to make us more alert to new possibilities to-day. A geologist or operator may unconsciously carry a local prejudice from one area into another. On the other hand he may enter the new area with no preconceived notions about it.

This point is well illustrated by the fact that European geologists familiar with the Fars and Asmari production of the old Persian fields were unwilling to recommend drilling on Bahrein Island in the Persian Gulf because this structure was eroded below the known producing formations of the Persian fields. An American company entering the area with no such preconceived ideas obtained excellent production.

A geologist who has done most of his work in relatively simple low-relief areas, or has been continuously employed in complicated areas of high relief, may retain certain misconceptions regarding such things as the necessary amount of structural closure, the effect of tight folding on reservoir porosity and permeability, the significance of thinning or rapid facies changes along a plunging nose, the influence of depth of burial or the extent to which igneous intrusions affect near-by sediments. His attitude regarding remoteness, the value of distillate production, and the advantages of unitization; or his unfamiliarity with small or queer-shaped land parcels, such as the arpent strips of south Louisiana, may aid or retard prospecting in new geological provinces.

Dry holes or unprofitable producers may take the edge off our enthusiasm

and delay further consideration of new districts or of a particular structure or horizon. Some years ago two of our members were discussing the future of West Texas; one considered the deeper possibilities excellent since practically all wells that had drilled below the Permian had logged showings; the other argued that if oil were present in producible amounts in the pre-Permian of West Texas, at least one of the deep wells that had already been drilled would have found it.

This brings up an interesting question. How many wells must we drill or what must we know about an area before we can venture to say that no further possibilities exist? This is pertinent to consideration of some of our older producing districts, and to future prospecting in Washington, Oregon, North and South Dakota, Idaho, Utah, Nebraska, and the southeastern states.

SUMMARY

The American petroleum industry has grown tremendously in the last 10 years. During this period exploration efforts resulted in discoveries that have increased net reserves of crude oil by 38 per cent. Nevertheless, during the last half of this period there has been a gradual decline in the rate of finding new high-quality fields.

In order to maintain our present reserve position, we must find nearly 2 billion barrels of new oil each year. Until research can suggest a new discovery method or provide us with a new set of oil-finding tools, our exploration effort will consist mainly of reworking many of the same areas in more detail and with closer teamwork between the various oil-finding groups. Many new fields undoubtedly lie hidden under some of the geological masks I have mentioned this morning, and some of our future oil will come from areas that do not look attractive to us at this time. If we can devise some way of effectively penetrating these masks and will examine all areas and all new ideas with an open mind, we will be in a better position to find these new supplies of oil.

Cheaper drilling would help to solve this problem, especially in those areas where favorable stratigraphic and structural conditions are hidden by the older rocks of an overthrust sheet or a thick mantle of volcanics. Where flat-lying high-velocity limestones are at or near the surface, the problem is up to the geophysicists. The water cover of the continental shelf can be effectively penetrated by our present prospecting methods but development may be retarded by economic, legal and possibly political factors.

Drilling costs have always been one of our major problems in exploration, as well as development, and probably always will be. The present high cost of water operations and of prospecting in remote or difficult areas on land suggests that we are entering an era of million-dollar wildcats and that possibly there should be more joint exploration ventures similar to "Operations Muskeg."

All areas of thick sediments, whether of marine origin or not, should be examined critically. Abnormally large areas of normal gravity should be reworked in more detail, and by different methods. In view of the variable nature of poros-

ity in limestones a tight section in one well should not prevent further consideration of the surrounding area. Exploratory wells should be drilled through the entire sedimentary section, unless there is positive evidence that no deeper possibilities exist, and all showings in wildcat wells involving intervals of reasonable thickness should be tested regardless of personal opinions or preconceived notions as to the importance of the showings.

It is apparent that we need more information of the type that only the drill can give. One of the most constructive moves we could make at this time would be to better adapt our oldest and most positive oil-finding tool to the immediate needs of the geologist. The designing of cheaper drilling equipment for deep geological investigations should be one of our major objectives in applied research.

In closing, I visualize increasing opportunities for applying the principles of geology in oil exploration. More geologists will be needed. Some will spend the greater part of their lives in foreign countries and must be carefully chosen for their adaptability. Others will be engaged at home in detail subsurface studies in local areas, and will be selected for their ability to tackle complicated problems and stick with them. More of the senior geologists with broad experience, imagination, and vision must be relieved of routine and administrative duties and allowed to work exclusively on the broader problems of finding new oil provinces.

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WHITHER EXPLORATION[1]

J. J. JAKOSKY[2]
Los Angeles, California

INTRODUCTION

Many developments in international politics during the past few months have created much concern over the adequacy of our petroleum reserves. Not only the leaders in the oil industry, but also many industrial, congressional, and military leaders are concerned over our ability to maintain a domestic production capacity sufficient to support the industrial and civilian markets, and if necessary, to meet the demands of another world-wide war.

Since 1938, the question of an adequate oil supply has been of vital importance. We know our oil production in the United States has exceeded the total discovery of new oil. Many and various factors have contributed to this unfavorable condition. The most important appear to be of a politico-economic and a technologic nature. For the purpose of my paper to-day, I would like to discuss certain of these factors which have had a direct bearing upon our professional work in economic geology.

One major factor which has fostered the unfavorable relationship between the production of oil and the discovery of new domestic fields is the type of controlled economy under which we have had to operate during the past decade. The petroleum industry is the second largest in the United States, and probably the most outstanding example of an industry that has developed under private initiative, where open competition and a sane economy have given us world leadership. When this condition was suppressed by unfavorable legislation and regulations, initiative was stifled and aggressive exploration was inhibited. During the war period of controlled price ceilings for crude oil, profits were not sufficient to yield a return adequate to stimulate exploration in the high-risk areas. Wildcatting was suppressed and much of the drilling was directed toward the proving-up of the more favorable prospects, and the extensions of known producing areas. This inhibiting effect[3] of too low a price has been particularly exaggerated after issuance of the "Hold-the-line Order" in April, 1943, which froze the price of oil at substantially a fixed level, while labor and material costs were allowed to advance.

[1] Presidential address, Society of Exploration Geophysicists, Los Angeles, California, March 25, 1947.

[2] Consulting engineer. The writer desires to express his appreciation for factual data from A. C. Rubel, vice-president, Union Oil Company of California; and for constructive reading of this paper by: Howard C. Pyle, Bank of America; William H. Geis, consulting engineer; Henry C. Cortes, Magnolia Petroleum Company; John Pierce, Western Oil and Gas Association; John Jakosky, Jr.; Henry Salvatori, Western Geophysical Company; Cecil H. Green, Geophysical Service Inc.; Sam Grinsfelder, D. L. Shepherd, and D. Ruesch, Union Oil Company of California; Wm. M. Rust, Humble Oil and Refining Company; and A. W. Knight, patent attorney.

[3] *Report on the Cost of Finding, Developing and Producing Crude Petroleum, Submitted to the Office of Price Administration, by the National Crude Oil Industry Advisory Committee, February 11, 1946.*

During this same period, our exploration difficulties continually increased. Since 1943 and until a few months ago, the average income from the sale of crude oil was approximately 35 cents less per barrel than the replacement cost of new oil. The industry as a whole has avoided bankruptcy by the simple expedient of operating chiefly on funds derived from the sale of crude oil obtained from producing properties discovered nearly a decade ago. A brief over-all picture of the increased replacement costs for new oil may be obtained from the data given in Table I,[3] which shows the relative costs during the past decade of the: *lease operating costs*,[4] the *drilling* or *development costs*,[5] and the *exploration costs*.[6]

TABLE I

Year	*Operating Costs*	*Development Costs*	*Exploration Costs*	*Total Cost of New Oil*
1936	0.262	0.212	0.180	0.654
1937	0.274	0.213	0.145	0.632
1938	0.311	0.201	0.163	0.675
1939	0.295	0.191	0.360	0.846
1941	0.292	0.199	0.262	0.753
1942	0.311	0.218	0.415	0.947
1943	0.307	0.296	0.434	1.037
1944	0.308	0.383	0.907	1.598

In the past 10 years, the *lease operating costs* have increased only about 17 per cent. There has been an average increase of about 70 per cent in basic wages and other costs during this time. To offset this increase in wages, there have been two factors: an increase in production per man-hour, due to the installation of better field equipment as the producing fields became stabilized; and secondly, greater production from wells as proration regulations were removed during the war emergency. Better operating efficiency has therefore held the *lease operating costs* below a value which might be expected in view of the general price rises during this period.

The *development costs* have increased approximately 80 per cent in the past decade. This is nearly 10 per cent greater than the average increase in basic wages and other costs and shows the normal increase due to: greater depth of wells, larger size of holes, heavier equipment, and the increase in the number of dry holes. The percentage of dry holes rose from 13.5 per cent to more than 27 per cent.

During the past ten years, however, our *exploration costs* have increased more

[4] Total operating costs divided by volume of production will disclose operating cost per barrel. *Ibid.*

[5] Total cost of oil wells completed each year, divided by volume of estimated oil reserves recoverable from such wells, approximates development cost per barrel on a replacement basis. *Ibid.*

[6] Total of finding costs, divided by the volume of new reserves discovered in the same year, approximates finding cost on a replacement basis.

than 400 per cent. Wages in exploration work have gone up somewhat comparable with the average increase in basic oil-field wages. Tending to offset increased labor and material costs, are the many advances which have been made in our geological and geophysical techniques. Yet with all of these advances, the *exploration costs* have increased 30 times more than the *lease operating costs*, and over 6 times more than the *development costs*.

The reason for this greatly increased exploration cost is due chiefly to the decrease in effectiveness of both our geological and our geophysical techniques, as we rework old areas and extend into the marginal areas.

Our exploration techniques have been in cycles, each extending over a period of a relatively few years. The first technique utilized surface indications such as oil seeps. Then came the period of creek-ology, which ushered in the trend theory; then we again reverted to surface indications as geology and plane-table mapping were employed to find structural highs.

During this time much wildcat drilling was being done. The wells were not too expensive due to their shallow depth. Then slim-hole and other systematic drilling techniques were introduced to work out structure covered by shallow overburden and unconformities. The relatively high cost of exploratory drilling encouraged the use of geophysical techniques, which were able to map the subsurface structural highs. Then we had the peak periods of application of refraction seismic, torsion balance, magnetometer, reflection seismic, gravity meter, and some geochemical and electrical work. The areas most amenable to the present geophysical and geological methods now have been well covered, and probably the more readily interpreted subsurface conditions diagnosed in terms of economic geology.

To-day, for lack of better methods, as we continue our search for the subsurface structural highs, the trend in general is toward the ultra refinement of present techniques, which comprises the careful evaluation of an area by the use of more intensive geology, where possible, supplemented by two or more geophysical methods. By correlation of the data from different geophysical methods, it often is possible to interpret some of the weaker anomalies, whose significance are not apparent from the application of one single geophysical method. Obviously the cost of such work, necessitating the combination of independent techniques, must be high.

If it were not for the limitations imposed by economic considerations, we could continue along the present lines of endeavor with more and more intensive application of the combined geophysical and geological procedures. Such a program will of course find additional oil, but its use can only result in increasingly greater costs. Thus the law of diminishing returns enters into the picture, as we rework old areas and extend into the less easily mapped marginal and the deeper areas. Often the development of these deeper structures is not overly attractive due to the greater cost of deep drilling, coupled with the fact that the deeper horizons generally have a smaller recovery per acre. The increased development and lease

operating costs, together with the lower productivity, far too often make the development of a deep-lying structure a risky marginal operation.

In the United States, the most important undeveloped areas remaining to-day are the covered or masked areas, complex fault accumulations, and the stratigraphic traps created by unconformities, pinch-outs, changes in porosity or sedimentation, and lensing. Nearly a third of the important oil fields in this country have been of the stratigraphic type, discovered by random drilling. This list includes such important producing fields as the Midway-Sunset, Coalinga, and Kern River here in California; Glen, Burbank and Bristow-Slick in Oklahoma; the East Texas in Texas; the Smackover in Arkansas; perhaps the new Delhi in Louisiana, and the Bradford in Pennsylvania. In addition, we have many smaller fields, such as the Cut Bank in Montana; and the shoestring pools of Kansas. Such a high frequency of blind discovery without the aid of geology and geophysics clearly indicates the much greater frequency of occurrence of the stratigraphic accumulations. Since our present exploration methods are not generally applicable to the detecting and mapping of stratigraphic traps, it is to be expected that unless some more effective technique of prospecting is developed very shortly, we will again revert to the drilling cycle of exploration. If this happens, we will have much exploratory drilling along stratigraphic trends, using less geology and geophysics, and depending primarily on actual drilling luck for success. In the past, such random drilling has been moderately successful in some areas and undoubtedly will find more oil in the future. The recent price increases for crude oil will stimulate this type of exploration. Such wildcat drilling, however, will not be as attractive as it was a decade ago, due to the greater cost of drilling and the limitations imposed by present laws and taxes on the financing of such operations.

In speaking of more effective techniques, do not visualize a refined crystal ball or the early evolution of a radically new principle of operation. We will undoubtedly continue to utilize the presently known properties of rocks *in situ*, perhaps much as employed in our present geophysical art. We have good reasons, however, to expect decided improvements in instrumentation, better use of field equipment, and more complete interpretation.

Interpretation is probably the least advanced of any of the components of successful exploration. This is due to the human inability of the interpreter to evaluate properly the effects on the geophysical data of the complex stratification and the lateral variations comprising the subsurface. The subsurface is an extremely complex three-dimensional region which the interpreter must diagnose with only the help of the very limited, incomplete type of data obtained from our present techniques.

Oftentimes a relatively minor improvement makes the difference between data having definite diagnostic value and data that may be ambiguous or even misleading. To-day, practically every major exploration organization is increasing its research activities, trying to discover new and better exploration methods.

Such research is groping into every field of scientific achievement in hope of utilizing new discoveries that have not heretofore been applied to oil exploration. It seems reasonable to believe that under such stimulated effort, new applications will be made of developments taken from other lines of science or industry. However, many new applications in nearly all fields of engineering, are being retarded now due to the policy of secrecy forced upon many industrial and research organizations during the past 5 years. This secrecy has been fostered by the malfunctioning of our patent system. Due to political interference in the administration of the patent office, it now takes years instead of months to get an application sufficiently advanced to evaluate its patent possibilities. As a result, secrecy is oftentimes advisable, if advantage is to be gained from the fruits of the research work. Such a policy greatly retards our national progress by inhibiting the dissemination of fundamental information. It also fosters unnecessary rivalry between scientists and laboratories, with the resultant duplication of much fundamental research and studies. Issued patents serve as reliable sources of information, and more important, stimulate early publication of technical papers. The patent background constitutes one of the interesting differences between applied geology and applied geophysics. Geology is an art almost wholly devoid of patents. Geophysics, on the other hand, due to its foundation of electronics and engineering, utilizes some 2,000 active patents, covering everything from galvanometers to drills.

In addition to the difficulty within the patent office itself, much confusion exists regarding the legal interpretation of patent claims. To illustrate one general trend: recent Supreme Court decisions have held that an indispensable ingredient of a patentable invention was a "flash of thought," originating in the mind of an individual. A majority of the 100,000 patents issued annually in the United States are for discoveries made in laboratories, staffed by specialists working as a group. Recent court decisions make many such patents invalid because of their group origin. This reasoning, if applied to petroleum exploration, would say that valid title to acreage should be given to a lone wildcatter who had a "flash of thought" disclosing the subsurface oil accumulation, but title to this same acreage should become public property if the discovery is the result of the usual careful work by a group of specialists, comprising for instance, the geologist, paleontologist, geophysicist, and the land men. In some recent cases, our higher courts appeared to be making their decisions so as to further political creeds rather than on an unbiased interpretation of those fundamental patent laws, upon which our industrial progress has been built.

Another illustration of the effect of political maneuvering upon our exploration efforts is the confusion regarding ownership of California tidelands and the submerged shelf along the Gulf Coast area. For nearly 170 years, the courts have decided that submerged lands were the property of the states; and 52 decisions of the United States Supreme Court have granted sovereignty to the states. Suddenly in 1936, an attempt was made to reverse this long line of decisions. After

much legal maneuvering and costly court work, there is now pending before the United States Supreme Court a new suit by the Federal Government against the State of California, "claiming that all persons who hold title or leases from the State of California on submerged lands are trespassers against the rights of the United States."[7]

At best, the exploration and development of submerged areas is a costly and difficult burden. Now, in addition to the technologic and economic problems, there has been added a legal burden. The systematic development of these tidelands and offshore areas has been, and will be, delayed to a great extent until the legal phases have been clarified.

Exploration activities have been stimulated by the price increases of crude oil during the past few months. A considerable margin must exist between the selling price of oil and its cost of replacement with new reserves, because "approximately 65 per cent of the gross income from the production of crude petroleum must normally be expended in the search for and the development of petroleum reserves to maintain adequate production."[8]

In addition to the recent price increases, a further incentive to exploration is possible by modifying our present income tax set-up, which now actually penalizes the financing of any intelligent long-range exploration program. In particular, tax structures should be adjusted to allow the smaller independent operator an opportunity to plow back into his business enough profit to make prospecting for new domestic fields profitable. This is difficult now because of the limitations on net operating loss carry-overs and carry-backs, and the limitation on deductions for geological and geophysical expenditures. In the past, a large part of our risk money for wildcat exploration has come from the smaller independent operators, who accumulated sufficient profits during their flush years, to drill succeeding wells. A more liberal interpretation of the revenue statutes would enable many operators to recover their initiative in exploration.

In summarizing the situation in which we find ourselves, it seems reasonable to believe that the present unsound condition now existing can be greatly improved by the correction of certain factors. Some of these factors are of political origin and should be corrected by changes in recent promulgated regulations and laws. The economic factor imposed by a too low price ceiling has been rectified recently by expiration of the wartime emergency act. Much yet remains to be done by proper changes in tax structures and income regulations. New technologic developments are needed and can be stimulated by improving and clarifying the patent situation, thereby allowing earlier publication of new fundamental and applied research. The cloud on the titles of tidelands and offshore areas should be lifted by an early action of Congress or the United States Supreme Court.

[7] Robert W. Smith, "That California Tidelands Case," *Mining and Metallurgy* (March, 1947), p. 170.

[8] *Report on the Cost of Finding, Developing and Producing Crude Petroleum, Submitted to the Office of Price Administration, by the National Crude Oil Industry Advisory Committee, February 11, 1946.*

The changes in the general conditions during the past few months indicates that neither extreme optimism or pessimism need be voiced for the present state of domestic exploration, providing proper encouragement is given exploration and new technologic developments. On the basis of geologic probability, we can be fairly certain that much oil still exists to be discovered in the subsurface. It seems reasonable to expect intensive exploration activity; and, if history repeats itself, new domestic reserves should be discovered.

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HIGHLIGHTS OF DOMESTIC DEVELOPMENT IN 1946[1]

K. C. HEALD[2]
Pittsburgh, Pennsylvania

The preliminary estimates tell us that proved reserves of oil, as of the first of 1947, range from about 21,200,000 to 21,900,000 barrels, depending on your choice of estimator. There is more petroleum in sight, to meet the demands of future years, than there was a year ago. Nevertheless, there are some districts where proved reserves declined, suggesting that these districts must, before long, borrow from more favored areas or otherwise supplement their declining supply.

Does this increase in reserves mean that geologists, during 1946, demonstrated ability to find new fields faster than they are needed to meet the growing needs of the country? The answer has to be "We do not know." For more than ten years the additions to reserves from revisions of earlier estimates, from extensions and from discoveries of new pays in fields found in past years have, year by year, materially exceeded the new oil credited to new pools. In 1946, the reserves credited to entirely new pools ranged from 1/6 to 1/10, depending on the opinions of the estimators, of the total additions. The remainder came from extensions and revisions.

This is not necessarily alarming. The large revisions and extensions mean that it is not possible, during the year of discovery, to appraise the importance of the discovery. It is our practice to talk only of the oil that is definitely in sight, and to let future years demonstrate that the deposit was larger and richer than we could predict with assurance. Guesses will vary about how long it should take to know the real magnitude of discoveries, but all students of petroleum reserves now realize that years must elapse after discovery before the recoverable oil in a field of real importance can be accurately estimated. They also know that every important change in the price of oil, in the cost of labor, in reservoir engineering and in many minor factors, will increase or reduce the amount of oil that can be recovered from wells and fields before economic conditions force their abandonment.

The importance of revisions that result from economic factors was demonstrated when Pennsylvania, the original oil-producing state, emerged from 1946 with more reserves than were in sight when the year began. This reversed a long period of decline. No important new fields had been found, but the estimators recognized that if the present price for oil is maintained or increased the recovery from existing fields, and perhaps from fields that once were abandoned, will be greater than could be anticipated a year ago.

The statistics for wildcat wells and for new fields discovered during 1947 are not reassuring. The oil-finders had a hard time. More wildcat wells were drilled in

[1] Read before the Association at Los Angeles, March 25, 1947. Manuscript received, April 29, 1947.

[2] Gulf Oil Corporation.

1946 than in any preceding year; more than twice as many as for any of the years before 1939. If discovery were in direct proportion to wildcatting effort, the number of new fields should have broken all records. Actually fewer fields were found than in 1945 or in 1944. Of course this means that the percentage of dry holes was high in 1946 when compared with the two preceding years. Such a record strongly indicates that unless some phenomenal fields are found, or improved oil-finding technique is developed, the number of wildcat wells must steadily increase if an adequate supply of oil is to be found.

The previously known reserves were not merely maintained, but were actually increased by the discovery of extensions to older fields and of new pays in those fields. Upward revision of the inadequate estimates of previous years and many successful completions of wells that were designed to extend or to find new pays in old fields made the percentage of success of all exploratory wells, which include both strict wildcats and extension wells, as good as in 1945 and better than for any year prior to 1945.

Events of interest and significance were by no means restricted to wells that found oil. For example, in Maryland and in North Carolina wells drilled to granite disclosed thick sections of Cretaceous sediments not dissimilar to those that are productive in Mississippi. The well in Maryland was drilled near the east coast and the one in North Carolina is only $\frac{1}{4}$ mile from the old Hatteras lighthouse and therefore is as far seaward as a location could be made and still be on land. The evidence indicates that even thicker sections of sediments overlie the granite east of these tests. The information from these wells, and particularly from the one in North Carolina, will affect the thinking about distribution and characteristics of sediments that may be oil-bearing as far south as the east coast of Florida and as far southeast as the northern part of the Bahama Islands.

Georgia received comparatively little attention in 1946, despite the enthusiastic press notices and vigorous land plays of past years. Perhaps the hopes of the wildcatters were once too high and must be given time to rebound from the impact of disappointment. Whatever the reason, only two wildcats, both dry, were recorded for the state in the trade journals.

Florida was the scene of much more prospecting activity. About 25 wildcats, all dry, were completed and others were drilling at the turn of the year. There was some encouragement in the form of slight showings of oil and of gas in rocks of Upper and Lower Cretaceous age, but nothing that remotely resembled commercial production. A deep dry hole near the south tip of the peninsula, and another which was being drilled on the Florida keys near the Key West Highway, demonstrate that the limestone and anhydrite sequence of Lower Cretaceous age becomes very thick near the south tip of the state. What lies below it in the southern part of the peninsula is unknown although regional considerations suggest that sedimentary rocks of Jurassic, and perhaps older ages, are present above the crystalline basement.

Two producers were added to the Sunniland field in Collier County, the only

oil field in the state. Like earlier completions, the wells found black oil of about 22° A.P.I. in limestone of Lower Cretaceous age at depths greater than 11,500 feet. The new wells are reported to be better than the earlier ones.

Alabama received the attention that might be expected for a state next door to so active a state as Mississippi. About 12 wildcats were drilled, most of them in the southern part of the state. All were dry. They contributed materially to an understanding of the stratigraphic conditions in the state and supported the inference, based on geophysics, that salt domes, either deep or piercement, such as those with which most of the fields of Mississippi are associated, are not to be expected very far east of the western border of the state. It seems probable that thick beds of salt in depth either are absent or that the salt could not break through the strong overburden and lift the formations into domes. If many fields are found in Alabama they will, for the most part, be in traps formed by folding or faulting not associated with salt, or in lenticular reservoir beds.

Few fields were discovered in Mississippi in 1946, but there were events which should stimulate the search for oil in strata of Lower Cretaceous age. In past years some gas and distillate were found in the Paluxy formation of Lower Cretaceous age in the Hub field of Marion County. Showings of oil and gas had also been noted in the Lower Cretaceous in a few deep holes. However, the important pay sands of Mississippi's fields were in the Eocene and the Upper Cretaceous, and the massive sand in the Tuscaloosa formation has been the objective of most of the deep exploratory wells. In 1946, production of gas and distillate from the Paluxy of Lower Cretaceous age was established in the Cranfield field, about 85 miles west of the Hub field, suggesting that intervening territory might have similar prospects. A well in Forrest County, about 35 miles north and east of the Hub field, set pipe at 15,726 feet which would be about 7,000 feet below the top of the Lower Cretaceous and conducted a series of production tests at various depths. The company that drilled the well has made no statement but there is reason to believe that a number of zones in the Glen Rose and perhaps in other formations of Lower Cretaceous age contained oil and gas.

Although the new discoveries added little to the reserves of the state, extensions of older fields more than compensated, so that the reserves at the beginning of 1947 were greater than those at the beginning of 1946. At least one important extension resulted from defying classical theory, moving downdip from an established oil-water contact, and finding a reservoir that did not extend over the top of the structure. In the vernacular of the oil fields the anticline was "baldheaded" as of this particular sandstone member.

In Louisiana the world's deepest oil-producing well was completed. Not only is this the deepest producing well in the world but, unlike many other deep wells, it is not called a producing well by courtesy because it can yield a few barrels per day. It came in from a perforated interval between 13,763 and 13,778 feet, good for 530 barrels per day through an 11/64-inch choke. Also, unlike many of the very deep producing wells, it yields oil of moderately low gravity—33° A.P.I.—in

contrast to the gas and distillate which are more to be expected from very deep wells. To complete the story, it is on the flank of Weeks Island in Iberia Parish, one of the Five Islands which were recognized as piercement salt domes before Spindletop in Texas was drilled, and which was tested and given up by a number of oil companies before the present holder of the acreage determined to learn what might be present at great depth. It was on Belle Isle, another of the Five Islands, that Captain Lucas, the discoverer of Spindletop, did some of his early prospecting which led him to undertake the Spindletop venture.

There was an extraordinary intensification of geophysical work, leasing, and some drilling in the waters of the Gulf of Mexico south of the Louisiana coast line. The activity extended some distance into waters claimed by the State of Texas. Studies of the regional geology indicate that the Miocene formations which are productive in coastal Louisiana, and to a lesser extent in coastal Texas, extend under the Gulf of Mexico and that even far out in the Gulf of Mexico they should contain course sediments. These Miocene strata are, in large part, of continental origin under the mainland but on the south, under the Gulf, more of the total thickness should be of marine origin. There is no apparent reason why they should not contain good source beds. Unquestionably they contain permeable layers which could serve as reservoir beds. Known irregularities on the sea floor are thought to be due to piercement salt domes. If this were a land area it would have received enthusiastic attention long since. During the year one hole, 5 miles from land, was drilled to almost 13,000 feet. Preparations are in progress for a test about 18 miles from land. The trade journals have carried descriptions of proposed methods to permit wells to be drilled in water several hundred feet deep, but none of these has been received with enthusiasm by the men who must drill the wells. It seems probable that, in the immediate future at least, the drilling will be done from platforms or foundations that can be solidly fastened to bottom and that will extend well above wave level. Presumably this will add $200,000 or more to the cost of an exploratory well, as compared with a well of similar depth drilled on land. Underwater geophysical work is also costly as compared with work on land. The total outlay will be recovered only if excellent wells with sustained yield are consistently completed.

Arkansas contributed little that was novel during 1946. New field discoveries were far from spectacular. Opinion varies as to whether reserves increased or declined. The mystery of why the Jurassic Smackover limestone, which is an important producing formation in the southwestern part of the state, has yielded nothing in the southeastern part of the state, although present and porous, apparently has not been solved. At least no explanation has been published.

There are wide differences of opinion about how much different districts of Texas contributed to the proved reserves of the state but the various opinions agree that in Texas, in 1946, more wells were drilled, more fields were discovered, more reserves were added, and more oil was taken from the ground than in any other state. As in most other states, extensions and revisions played a much greater part in bolstering the reserves than did new fields.

Information developed during recent years has led many to believe that a number of fields, including the great Seeligson field in Bee County in southwest Texas, will be proved to be only parts of one mammoth field, larger than any other in the United States, except East Texas. If this is true, further substantial additions to the oil reserves are in the offing. The fields involved in this speculation are characterized by many lenticular sands. Some areas occupied by the highest part of the present anticlines apparently were almost or quite emergent from the sea while sands accumulated offshore so that oil pays which are absent over the tops of the folds may be present on their flanks. Such conditions demand persistent and rather blind drilling if all possible reservoirs are to be found and drained.

Abnormally high pressures in wells in the Gulf Coast have been observed in some areas but if reported measurements are authentic, all records were broken when the Christmas-tree gauge on a well in Brazoria County recorded a pressure of 8,225 pounds. The well was yielding gas from perforations at 11,012–11,014 feet. Theoretically, such abnormally high pressures can exist only in a lenticular reservoir of comparatively small extent but the discoverer may be compensated by the volume of gas which may be compressed into limited space at such pressure.

In West Texas, both new discoveries and important extensions continued to demonstrate the importance of formations intermediate between the comparatively shallow oil-yielding beds in the upper part of the Permian section, in which the early fields of the Permian basin secured their oil, and the Lower Ordovician formation, which was proved to be important years ago when it was opened in the Big Lake field of Reagan County. For some years, one or the other of these formations was the objective of the wildcatter. Now much oil is produced from three or more additional Permian formations, from the Pennsylvanian, the Devonian, the Silurian, and the Upper and Middle Ordovician. It is anticipated that some of these formations will contribute important pools in the future when conditions which determine whether or not they are locally present with favorable characteristics are better understood. This probability is indicated by the present production from the Devonian strata. For some years showings in the Devonian rocks were ignored. Probably some wells were drilled through oil-bearing Devonian and Silurian strata without detecting the presence of oil since, in some instances, staining is not obvious although tests with solvents or with the fluoroscope show that oil is present. To-day, the TXL pool of Ector County, one of the important pools of West Texas, produces much of its oil from the Devonian.

Before the Permian was deposited, the Permian basin was folded and then was peneplaned so that Permian rocks may now be in contact with granite or with any pre-Permian formation up to and including the Pennsylvanian, depending on the amount of deformation and of bevelling that preceded Permian sedimentation. Petroleum geologists and geophysicists, who work in this region, have an interesting and intricate task if they are to outline correctly the pattern of the bevelled edges of older formations beneath the Permian floor, even though the task is

somewhat simplified by reasonable uniformity in character and in continuity of the pre-Permian sediments.

In 1946, Oklahoma ranked third and Kansas fifth in the tabulation showing total wells drilled in each state. They ranked third and fourth, respectively, in exploratory wells. Yet they shared with California, Michigan, New York, and Ohio the dubious honor of having smaller proved reserves at the end of the year than they had 12 months previously. This was not due to lack of effort. In fact, it is to the credit of Oklahoma geologists that the percentage of new reserves that were added by new fields was higher than in any other major oil-yielding state. It is apparent that available subsurface information is being studied intensively for many of the new discoveries were in areas that have been extensively drilled in years past.

Developments in south-central Oklahoma give some reason for hope that new discoveries will be made in areas where prospective formations are so deep that comparatively little testing has been done. The western part of the state, which seems to be the real hope for a rejuvenation of Oklahoma, has not responded encouragingly to the efforts of the wildcatter.

The record of Kansas in 1946 was much like that of Oklahoma. Nothing transpired to create a real expectation that important fields will be found in the sparsely drilled parts of the state. In Kansas, as in Oklahoma, the westernmost part of the state has, thus far, failed to show promise.

In Nebraska and adjacent South Dakota, the end may have come to a persistent effort to develop oil fields on or near the Chadron anticline, in the northwest corner of Nebraska and the southwest corner of South Dakota. Drilling had been preceded by work in the Black Hills where the formations that should be represented in the Chadron area crop out. Geophysical work of various types was done by several companies. The usual land plays followed, after which one company drilled five or six deep wells to test all possibilities down to the granite. The old arch, first mapped by Darton about 50 years ago, refused to surrender any of its oil, if oil it has.

Nebraska has been the scene of extensive geophysical work, careful geological work, and a limited amount of drilling which penetrated all formations that might yield oil. The story of the prospecting in this state and in the Dakotas on the north, like that of the Salinas Valley of California, demonstrates that it takes something more than a combination of anticlinal structure, marine sediments, and permeable beds to yield oil fields. We will not understand the presence or absence of oil until we know how and from what oil is made and how it may be dissipated if once it is formed.

There were interesting events in Wyoming, even though the new oil that was discovered little more than balanced the oil that was withdrawn from the ground. In fact, it is remarkable that the new reserves equalled the withdrawals because less than 200 wells were drilled in the state during the year and less than one-tenth of the new reserves are credited to new fields. The small number of wells

was the more remarkable because geologists, geophysicists, and lease men were active through the year, outlining new prospects and acquiring lands which must sooner or later be drilled.

The possible effectiveness of geophysical work in the Big Horn basin was demonstrated by a wildcat well in Washakie County, which came in as an excellent producer from the Embar formation through perforations from 9,990 to 10,020 feet. It is reported that little, if any, sign of favorable structure is apparent in the outcropping formations of Tertiary age, which are separated by a great unconformity from the folded rocks in which the oil was found. This discovery dealt a blow to the theory held by many geologists that any worthwhile structure in Wyoming has some recognizable surface manifestation.

Another notable discovery was made by the deepest well in Wyoming, drilled in Uinta County in the southwestern part of the state. At this location there is some evidence of surface structure. Unlike most wells that set depth records, this one produced its oil almost at the bottom of the hole. It yielded gas and distillate from 12,674 feet and the total depth was 12,895 feet. With its completion, Wyoming joined the roster of the states which have production from below 12,000 feet.

A third item of interest was the discovery of Pennsylvanian oil in the Tensleep sand on the Quealy dome in Albany County. The Laramie basin has long yielded oil from formations above the Pennsylvanian but this is its first production of Pennsylvanian oil. The Pennsylvanian has now been proved productive from the north line of the state at Elk Basin almost to the south line of the state.

Only one field was found in Colorado during 1946 and the importance of this field remains to be demonstrated. It is on the Elk Springs structure, about 25 miles northeast of the Rangely field. Oil was found in the Weber sandstone of Pennsylvanian age, which is the producing formation at Rangely. In spite of this poor discovery record, the reserves in Colorado increased 66,000,000 to 90,000,000 barrels, depending on the varying opinions of the estimators. These increases were due, almost entirely, to extensions of the Rangely field and to revisions of estimates of its probable yield. The differences of opinion may be due to varying ideas about the proper recovery factor to apply to the hard thick sandstone which is the producing formation in the field. The recovery factor is a figure by which estimators multiply the results of their detailed computations of pore space, sand thickness, connate water, shrinkage, and gas in solution in order to come out with the actual recovery which they feel will be most likely.

Exploration in New Mexico was concentrated in the southeast corner of the state, with some attention given to the San Juan basin, in the northwest corner of the state. No fields with outstanding performances were discovered, but both extension and wildcat drilling contributed to the growing promise of producing formations in the lower part of the Permian and in pre-Permian formations. Wildcat wells demonstrated that Devonian and Ordovician formations, equivalent in age and apparently in other characteristics to stratigraphic units that are richly

productive in West Texas, are present in Eddy County, approximately 75 miles west of the westernmost wells in which they had been observed 2 years ago. In the San Juan basin, geophysical parties were active. Deep drilling, which is the vogue in other areas, reached this remote district and on the southern Ute Indian Reservation, in San Juan County, just south of the state line, a gas well reported good for 20 million cubic feet per day, was completed in the Paradox formation of Pennsylvanian age at the depth of 9,303 feet. This gives some suggestion of drilling depths which must be overcome if the Pennsylvanian is to be reached in the more central part of the San Juan basin, since the well is moderately high on the northwest rim of that basin.

California had a discouraging year. The estimators are agreed that proved reserves declined, although they are not unanimous on the amount of the decline. This decline would have been more pronounced had it not been for excellent extensions to several major fields and particularly to the Wilmington field. Exploratory drilling was a discouraging business. Very few new fields were discovered and only one of these has been generally declared to be of possible importance. During the past 20 years, intensive search has discovered all fields that could be found easily, either by study of available geology or by the geophysical work that was available. The distribution of known oil fields indicates that there should be undiscovered pools in many areas but work of extraordinary quality or blind drilling, guided by extraordinary good fortune, is needed if they are to be found. At the end of the year, California had the satisfaction of having wrested the record of the deepest well in the world from Texas. At the present writing, this fleeting honor is held by Oklahoma.

There are other oil-producing states which have not been mentioned in this brief review because nothing of particular interest was noted in their records for the year. It is worth mentioning that Illinois maintained, and even substantially increased, its proved reserves even though this now must be done by the discovery of small pools and by minor extensions of such pools. Much of the credit is due to the fact that wells are comparatively shallow and wildcat ventures, therefore, are inexpensive. More wells were drilled in Illinois in 1946 than in any state except Texas, Pennsylvania, and Oklahoma, and more exploratory wells were drilled than in any state except Texas. This same factor of inexpensive drilling also helped to sustain the proved reserves of Michigan.

DEEP DRILLING

Year by year, the drilling depth records, both for individual states, and for the nation, are replaced by new ones. In 1946, California had the deepest well in the world in the Pacific Western Oil Company and Getty's National Royalties No. 1 in Sec. 5, T. 26 S., R. 22 E., Kern County, which had attained the depth of 16,668 feet in Miocene rocks. The Standard Oil Company's (New Jersey) Hatteras Light No. 1, which was dry in granite at 10,054 feet, gave North Carolina its first well with a 5-figure depth. The same company's Maryland Esso No. 1, in

Worcester County, bottomed in granite at 8,000 feet, established a new record for Maryland. The record for Florida was broken when the Gulf's State of Florida No. 1, on Big Pine Key, south of the main peninsula, entered the new year with a depth of 14,070 feet. In Mississippi, the Superior Oil Company's Cassie Bradford No. 1, in Sec. 1, T. 3 N., R. 13 W., Forrest County, reached the total depth of 15,730 feet in the Lower Cretaceous and showed as an oil well at a shallower depth in the Lower Cretaceous.

A new depth record for Indiana was set by the Continental Oil Company's Cooper Estate No. 1, Sec. 12, T. 3 S., R. 14 W., reported to be in Trenton limestone at its total depth of 6,408 feet. In Kentucky, the California Oil Company's Spears No 1, in Lincoln County, abandoned in granite at 6,117 feet, was deeper than any well drilled previously. In Oklahoma, the Superior Oil Company's Weller No. 51–11, in Sec. 11, T. 8 N., R. 12W., Caddo County, easily captured the state's deep drilling laurels when it attained the depth of 16,350 feet in Pennsylvanian strata in 1946. In early 1947, this well was drilled deeper to capture the world's record. A new depth mark for Louisiana was set by The Texas Company's State Barataria Bay No. 2, in Sec. 5, T. 21 S., R. 25 E., Jefferson Parish, which was finished at 14,577 feet in Miocene sedimentary rocks.

In Colorado, the Texas Company's Unit No. 20, in Sec. 34, T. 3 N., R. 94 W., easily held the state's depth record when it stopped drilling at 12,702 feet in limestone of Mississippian age. In Wyoming, the Mountain Fuel Supply Company's Union Pacific Railroad No. 1, in Sec. 8, T. 16 N., R. 112 W., Uinta County, surpassed all earlier records when it reached the depth of 12,894 feet in Jurassic rocks. In Montana, the Carter Oil Company and Phillips Petroleum Company's joint test, Weaselhead No. 1, in Sec. 28, T. 34 N., R. 12 W., Glacier County, was abandoned in limestone of Mississippian age, at the depth of 10,102 feet, a new record. In Oregon, The Texas Company's Cooper Mountain No. 1, in Sec. 25, T. 1 S., R. 2 W., Washington County, captured a new record for that sparsely drilled state when it reached the depth of 9,263 feet.

In establishing these records, the drillers, engineers, and equipment manufacturers have thrown a challenge to the oil-finders, for in most of the oil-yielding states, wells have been drilled deeper than commercial oil has been found. Failure to establish important new reserves at great depth can not be laid at the door of the men who drill the wells.

The deepest producing well in the world is the Shell Oil Company's Smith State No. 2, completed in 1946 on the Weeks Island dome, in Iberia Parish, Louisiana, which was good for 530 barrels per day from Miocene strata at the depth of 13,778 feet. This is almost 3,000 feet shallower than the world's deepest test. It remains to be proved that there are important oil fields, or even gas fields, at depths of 14,000 feet or more. At present we can see no good geologic reason why there should not be such fields. We know that formations, which have been proved productive in oil fields, are present in deep basins at depths far exceeding 14,000 feet. There is no evidence that at great depths the rocks will be too im-

permeable to surrender their oil. The temperatures at depths of 14,000 feet or more in some of the sedimentary basins, are lower than those that have been recorded in areas where deformation has been intense or where there has been comparatively recent igneous activity. The fact remains that very deep tests, some of which unquestionably are well located with respect to structural traps, have thus far failed to yield either oil or gas.

GEOPHYSICAL METHODS

The only striking addition to geophysical tools or technique was the airborne magnetometer, which was extensively publicized in the trade journals during 1946. This was a pre-war invention designed to expedite and increase the accuracy of magnetic surveys. It was adapted to military use as a tool for detecting submarines. Only to-day is it coming into use as an aid in geophysical prospecting. When magnetic methods first were introduced they were enthusiastically used. Inability to interpret results led many companies to abandon this geophysical tool. Improved understanding of the significance of magnetic measurements has resulted in renewed interest in magnetic work.

Seismic technique improved during the year. This statement is not based on specific instances so much as on the knowledge that any application of science, as young as is applied seismology, must inevitably advance. The science has not, however, overcome many of the difficulties which have hampered or defeated attempts to map areas where stratigraphy and structure are complex. In particular, no satisfactory method has been developed to detect and compensate for sharp velocity changes. Uncertainty must always be attached to the interpretation of seismic work in areas where deep wells do not provide information concerning stratigraphy, regional structure, and regional velocity.

Gravitational work is still being done on a large, but on a diminishing, scale. It has been extended to water-covered areas through the increasing use of gravimeters designed for under-water work.

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HIGHLIGHTS ON DEVELOPMENTS IN FOREIGN PETROLEUM FIELDS[1]

L. G. WEEKS[2]
New York, N.Y.

The writer was assigned the job of reporting to the Association at its annual meeting in Los Angeles on recent developments in foreign petroleum fields. On looking into the assignment, he found that activity in the search for or development of petroleum has been carried on in no less than seventy foreign countries in recent or post-war years. The scale of these activities ranges from that of Venezuela with her more than one million barrels of daily production in 1946 to that of countries like Sweden, where in a program of oil search in the southern part of the country the Government completed two wells in the past 2 years, in one of which a showing of oil was reported.

Only the highlights of the activities in such a large number of countries can be reviewed within the scope of this paper. As this is the first review of this nature for the Association, the account of recent developments in most countries is prefaced by a brief statement of historic background interest.

In addition to his colleagues, the writer is indebted to the following gentlemen for supplying him items of interest on the country or countries mentioned after each name.

Norval E. Baker	Iraq, Syria, Palestine, Lebanon and Qatar
Edward Beltz	East Indies
D. Dale Condit	India and Australia
Arthur A. Curtice	Chile and Brazil
J. Brian Eby	Austria, Hungary and Germany
Earl B. Noble	Paraguay
Frank Reeves	Germany
John L. Sullivan, Under Secretary of the Navy	Alaska
W. B. Wrather, Director, United States Geological Survey	Alaska

It is proposed to take up the principal developments of interest country by country, stressing most particularly exploration. We shall begin with Alaska and continue southward through the Western Hemisphere, then consider successively the countries of Europe, the Near East, the Middle and Far East, the East Indies, Australia and, finally, the balance of Africa not included under the Near East. The areas subject to our remarks may be followed on the accompanying set of maps on which are broadly sketched the sedimentary areas and the developed and more newly discovered oil fields. For simplicity we have shown the countries of Europe with their pre-war boundaries. Appended also is a table of cumulative world oil production by countries, and the average daily yield for each

[1] Read before the Association at Los Angeles, March 25, 1947. Manuscript received, April 18, 1947.

[2] Chief research geologist, Standard Oil Company (New Jersey).

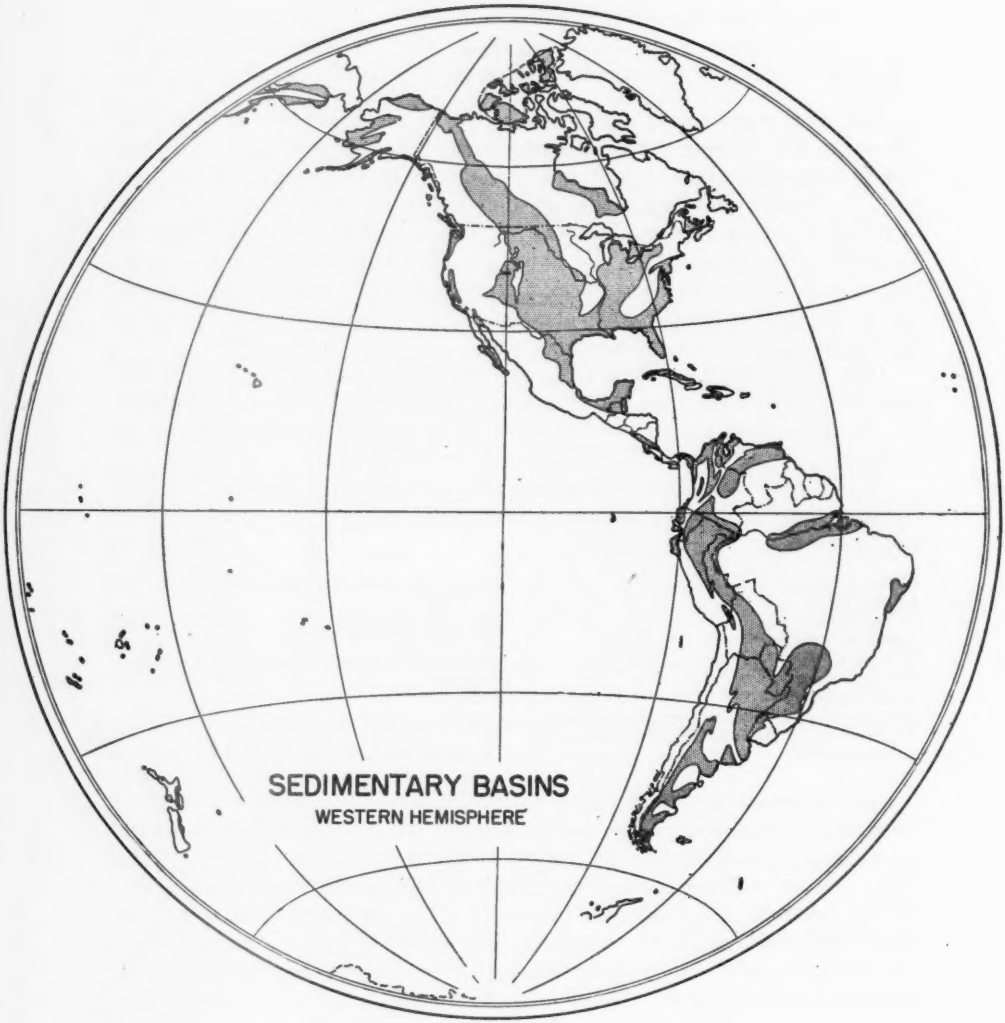


FIG. 1

country for the years 1946 and 1939. Another table lists the number of geophysical crews in operation in 1946 by countries.

Due to the recent World War and conditions since its close, there is a lack of reliable information on some countries. Our remarks concerning developments in such countries are general and are based on what is considered the most reliable information available to us.

WESTERN HEMISPHERE

ALASKA

For security reasons there has been a greatly diminishing amount of information available on developments in the northern Alaska Cretaceous basin in which the 35,000 square-mile Naval Reserve No. 4 is located.

Since the close of the war, exploration work initiated by the Navy during the war period has been contracted to Arctic Contractors. This American company is owned half by the exploration firm of Hoover, Curtice and Ruby and one-fourth each by C. F. Lytle Company, and Green Construction Company, both of Des Moines, Iowa. The operations are carried on under the general management of Bart Gillespie under the supervision of the Director of Naval Petroleum Reserves and the Operating Committee of the Navy.

It is reported that geological mapping, geophysical work, and other activities are being carried forward on a considerable scale, continuing through the winter months. Further exploration activities and the manner of continuation of operations will be dependent on the results of these surveys and the drilling operations. Recent published reports indicate that the first test for oil, Umiat No. 1, begun in 1945 on an anticline in the eastern part of the Reserve, may be abandoned at a depth below 6,000 feet. It is reported that several sands with good oil or gas saturation but inadequate porosity were drilled. Oil seepages occur in various parts of the basin, the most prominent and best known being those near Cape Simpson, east of Pt. Barrow.

The foregoing covers items that have been published in trade journals *et cetera*. The following is taken from a statement kindly supplied the writer by John L. Sullivan, Under Secretary of the Navy.

> In general the area, north of the Brooks Range, in which Naval Petroleum Reserve No. 4 is located consists of a broad coastal plain of low relief, covered by tundra and innumerable shallow lakes, extending inland from the Arctic Ocean to beyond the seventieth parallel of latitude. Beyond the lake country the surface of the land rises gently in rolling hills becoming higher as the Brooks Range is approached.
>
> This is a region where rock exposures are poor even along the channels of the many rivers and smaller streams generally trending northward toward the Arctic Ocean. Surface geology is extremely difficult to work out under existing conditions and the Navy has, therefore, tried about all the accepted methods of geological and geophysical exploration to determine the detailed structural geology of the exposed Upper Cretaceous sediments.
>
> It was first thought that relatively shallow core holes could be drilled on the low lands and that by correlating strata between them the underground structures could be delineated. The permafrost zone, averaging in thickness more than 600 feet, however, made

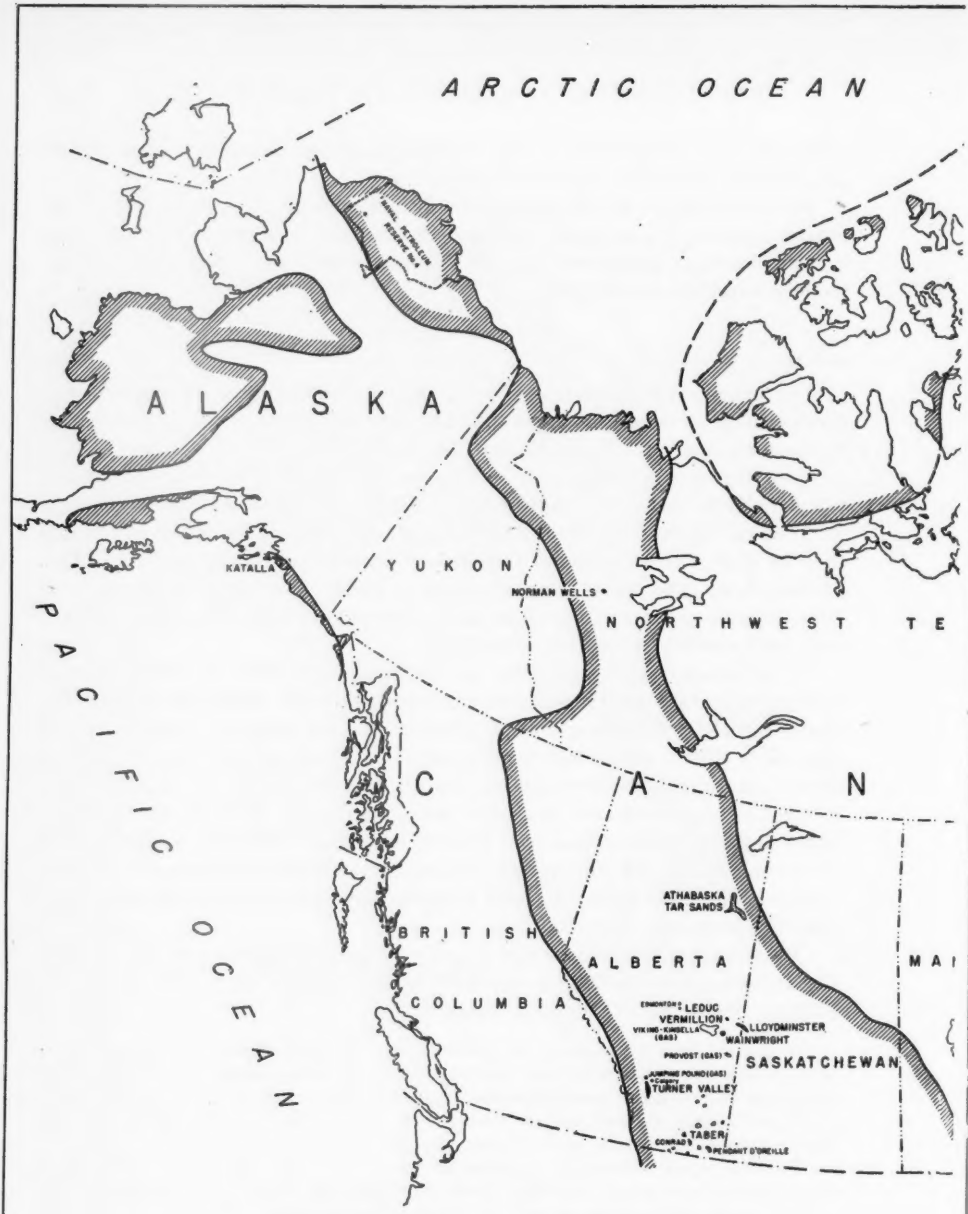

ARCTIC OCEAN
ALASKA
NAVAL PETROLEUM RESERVE No. 4
KATALLA
YUKON
NORMAN WELLS
NORTHWEST TE
PACIFIC OCEAN
C A N
ATHABASKA TAR SANDS
BRITISH COLUMBIA
ALBERTA
MA
EDMONTON
LEDUC
VERMILION
VIKING-KINSELLA (GAS)
LLOYDMINSTER
WAINWRIGHT
PROVOST (GAS)
SASKATCHEWAN
ATHABASCA POUND (GAS)
TURNER VALLEY
TABER
CONRAD
PEKISKO D'ORIENTE
CANADA AND ALASKA
SEDIMENTARY BASINS AND OIL FIELDS
0 100 400 800
MILES

FIG. 2

GREENLAND
ATLANTIC OCEAN
A
D
A
HUDSON BAY
QUEBEC
NEWFOUNDLAND
ONTARIO
STONY CREEK
MARITIME PROVINCES
ONTARIO FIELDS

such exploration too slow and tedious to be practical since it frequently necessitated drilling upward through ice to get the bit out of the hole. The difficulty of moving the core hole outfit over the swampy tundra also caused material delay and added to the expense.

Eventually a program consisting of trimetrogon aerial photographing of the area by the Army Air Force and the compilation from the photographs of preliminary base maps on a scale of 1:48,000 by the U. S. Geological Survey to provide control sheets for reconnaissance crews engaged in geologic and geophysical mapping, was followed.

Magnetic airborne detector equipment invented for anti-submarine warfare was modified with the result that a "flying magnetometer" capable of rapidly measuring magnetic anomalies was developed. This instrument, it was believed, might uncover leads which could be checked by detailed surveys with the gravimeter and the seismograph to delineate buried geologic structures favorable for drilling.

The Navy Department, through the Office of the Director, Naval Petroleum Reserves and the Bureau of Yards and Docks is carrying on this important work in close liaison with the U. S. Geological Survey of the Department of the Interior.

During 1946 five geological parties of the U. S. Geological Survey were engaged in reconnaissance work in the Reserve. This work is being done by the Survey with funds supplied by the Navy. Geophysical surveying with the gravimeter and seismograph, core hole and test well drilling, as well as all construction and transportation are performed under a civilian contract with industrial specialists in such work.

Alaska's only oil production, totalling 300,000 barrels, has come from the small Katalla field in a narrow Tertiary basin on the southeastern Alaska coast. Thirty-one shallow wells were drilled in the Katalla area between 1904 and 1919, about 14 of which produced a light grade of oil. A small refinery was built here, which later burned down. Farther east in the basin, in the Yakataga area, the General Petroleum Company drilled a 2,005-foot well in the 1920's on a sharp structure near the coast.

In the Cook Inlet-Cold Bay areas along the southwest-trending coast of the Alaska Peninsula, is a narrow belt of folded Jurassic and Triassic sedimentary rocks in which oil seepages occur. Several wells were drilled prior to the war on anticlines in the Cold Bay area, the deepest reaching 7,576 feet; and an 8,775-foot well was drillled on the Iniskin Peninsula northeast of Cold Bay. Minor showings of oil were reported in some of these wells.

During the war all of the better known potentially petroliferous areas of Alaska were closed to exploration by Public Land Order 82. This order has been rescinded for all areas except northern Alaska. No petroleum exploration was undertaken by private industry during or since the war. It is understood that several companies, some of which now have holdings in Alaska are planning activity in the field.

CANADA

A number of important wildcats have been drilled in the Foothills of Alberta since 1940: Imperial's Coalspur 1, Brazeau Syndicate 1, Imperial-Shell's Stolberg 1, Royalite's Wildcat Hills 1, and three wells by the Shell Company on the Jumping Pound structure. Only the initial Shell well on the Jumping Pound structure is rated as a new discovery, but the third hole encountered gas and

water. The other wells have supplied valuable information on Foothills type structures, for in both the Brazeau and Stolberg wells the limestone was found in at least three separate blocks; this disproves any notion that, when the limestone is encountered, the possibility of finding additional sole-faults is eliminated.

Wildcat drilling in the Southern Plains has uncovered three fields: Conrad, Taber, and West Taber, none of which can be rated as commercial. Minor discoveries in the Madison limestone have been most disappointing in the Plains, with almost all the wells going to water rapidly. An important development in the Southern Plains during 1946 was the discovery by McColl-Frontenac (Texas Company) of a major gas field southwest of Pakowki Lake, known as Pendant d'Oreille (T. 2, 3, and 4, R. 8 and 9 W. of 4th Meridian). The gas is found in the Bow Island sand of Colorado or lower Upper Cretaceous age at 2,000 feet.

In the Northern Plains, Imperial Oil Limited, when wildcatting for oil in the Viking-Kinsella area, found that the gas field extended over many townships, and it carried out an active program to establish sufficient reserves for a Fischer-Tropsch plant, in case it is necessary to make synthetic gasoline through the failure to find new crude reserves. With a similar objective the McColl-Frontenac and Shell companies are, respectively, continuing exploration of gas reserves in the Pendant d'Oreille and Jumping Pound areas.

Exploratory drilling in the Lloydminster area during 1946 by independent operators proved a large reserve of low-gravity crude. The field was extended 9 miles northwest and about 9 miles southeast in Saskatchewan, giving an over-all length of 26 miles and a possible width of 3 miles or more. The main producing formation is soft unconsolidated sand 160 feet below the top of the Lower Cretaceous, but there are also other producing beds in the Lower Cretaceous. Production appears to be related to favorable sand conditions where these sediments apparently drape over a terrace or fold in the Paleozoic; therefore, the sands are considered to be a shore-line or shoal deposit. The wells in the field vary considerably in production, but most of them produce 30 barrels a day or less. The sand is not a continuous "sheet sand" but a series of interfingering and overlapping lenses of large area.

Imperial Oil, Ltd., made a minor oil discovery in the Provost area which, upon further exploratory drilling, was proved as a sizeable gas field in the Viking zone, but non-commercial as an oil field, in the uppermost part of the Lower Cretaceous. The trend in wildcat drilling appears to be moving farther northwest with the Anglo-Canadian, McColl-Frontenac, and Imperial exploring the eastern flank of the Alberta syncline.

In February, 1947, Imperial's Leduc 1, located 18 miles southwest of Edmonton, made what may develop into the most important discovery in Alberta since Turner Valley. The well will apparently make a good producer of 38° A.P.I. oil in the Devonian, which is a new producing formation in Alberta.

During 1946 five major oil companies combined to initiate exploration of the "Muskeg Anticline" in the remote north-central foothills of Alberta, 205 miles

west of Edmonton. While regarded as promising, the operation has necessitated the construction of a 75-mile road from the nearest railway point to the drill site. Drilling depth to the Madison limestone, based on the geology of the region and seismograph survey, is estimated at about 10,000 feet.

Ten geophysical crews, many geological parties, and about 60 drilling rigs operated in western Canada in 1946, and a million dollars a month were being spent on new development in the latter part of the year.

Drilling initiated in 1942 by the Geology and Mines Branch, Department of Mines and Resources, north of Fort McMurray in the extensive Athabaska tar sands area has proved a particularly rich section of the sands estimated to contain about half a billion barrels of oil. The sands contain 12 to 18% of 10° A.P.I. oil by weight. The program of exploration is now being discontinued. It was carried on as a war measure. Current plans call for turning the operations back to Abasand Oils Ltd., who had built a small extraction and refining plant near Fort McMurray and had initiated exploitation of the sands prior to the war.

Operations on the Canol project, begun in 1942 at Fort Norman in Northwest Territories where oil had been discovered by the Imperial Oil Company in 1920, ceased in March, 1945, after 60 commercially productive wells out of 67 holes, 4 of them semi-exploratory, had been drilled. Nineteen other exploratory wells, all dry, were drilled on outlying prospects in the general region.

Little of significance has developed during the year in the old producing fields of Ontario Province. In the Maritime Provinces, the Sun Oil Company's Smith 2 was reported drilling at 8,700 feet in the Mississippian Albert series in southern New Brunswick, near the area of the small Stoney Creek gas and oil field. No. 1 was abandoned at 6,506 feet in the Mississippian Windsor Salt series. It is recalled that the Hillsborough well drilled in a shallow bay off Prince Edward Island was abandoned in 1945 at 14,630 feet in the same salt series.

Canada's approximately 20,000 barrels present daily production provides only 15% of her crude-oil requirements. About 89% of this oil comes from the Turner Valley field. Cumulative oil production in Canada totals about 116 million barrels.

MEXICO

Cumulative production in Mexico amounts to about 2,255,000,000 barrels. Daily production is around 135,000 barrels from about 4,600 wells. About 72,000 barrels or somewhat more than half of present daily output comes from Poza Rica, followed by the Golden Lane (23,000 barrels), Panuco or North Fields (20,000 barrels), and the Isthmus of Tehuantepec (17,000 barrels), with minor production from other miscellaneous areas. No significant new fields have been found in Mexico since the discovery of Poza Rica in 1930.

About 20 rigs were running in the latter part of 1946. An average of about 7 of these are on exploratory work. The remainder are on development drilling. About 50 wells were completed during the year. Two of these wells were com-

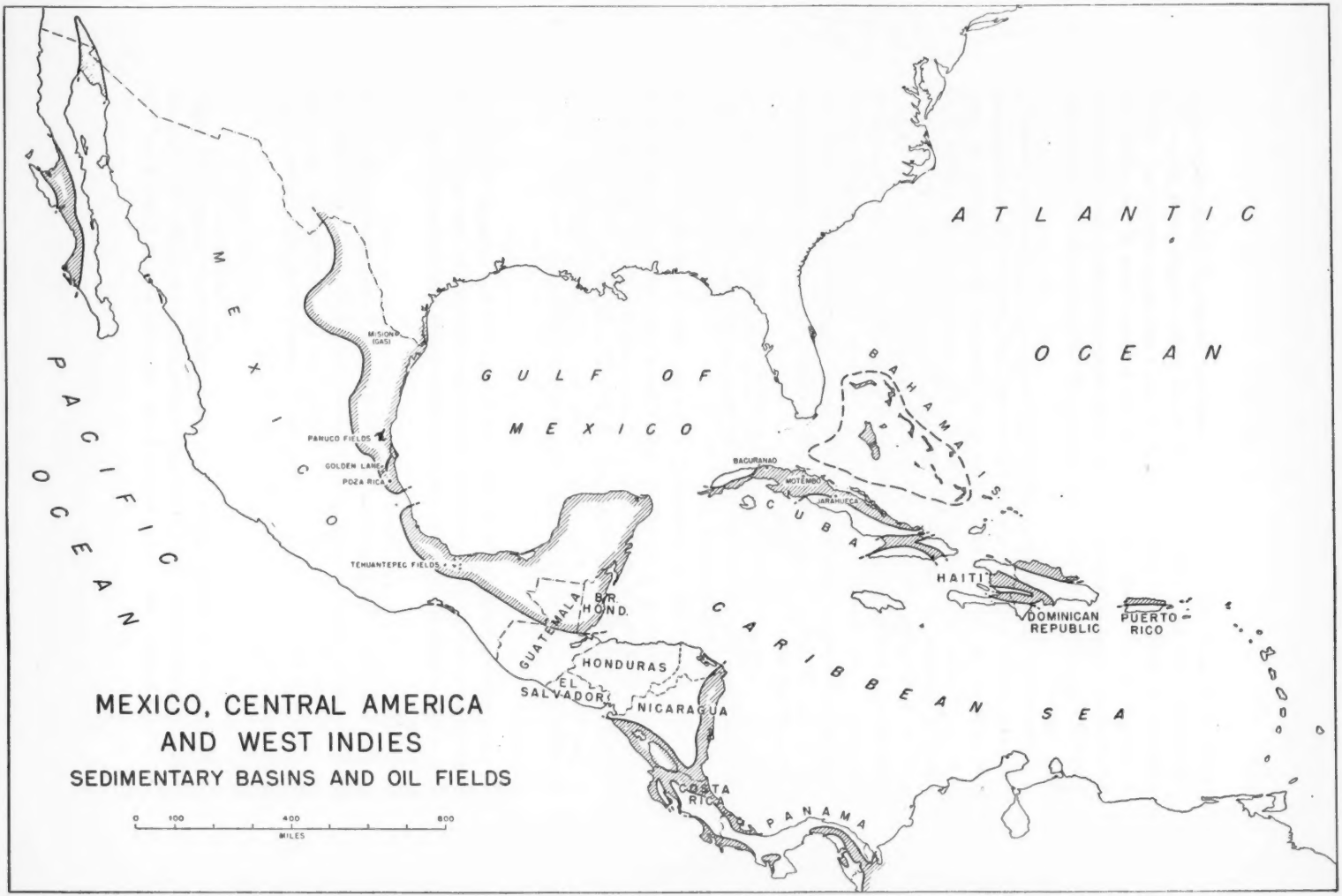

MEXICO, CENTRAL AMERICA
AND WEST INDIES
SEDIMENTARY BASINS AND OIL FIELDS
0 100 400 800
MILES
PACIFIC OCEAN
MEXICO
GULF OF MEXICO
ATLANTIC OCEAN
BAHAMAS
CUBA
HAITI
DOMINICAN REPUBLIC
PUERTO RICO
CARIBBEAN SEA
GUATEMALA
B. HOND.
HONDURAS
EL SALVADOR
NICARAGUA
COSTA RICA
PANAMA
MISION (GAS)
PANUCO FIELDS
GOLDEN LANE
POZA RICA
TEHUANTEPEC FIELDS
BACURANAO
MOTEMBO
ARAMUECA

FIG. 3

pleted in the small Mission gas field in northeast Mexico. At least 6 dry or noncommercial wells were completed in the North Fields; about 12 producers were added to the productive area of Poza Rica, and about 12 producers were drilled in the Isthmus of Tehuantepec fields. On the Isthmus most of the drilling was concentrated on development of the El Plan structure where a deeper sand was found in 1943. About 10 other wells drilled on the Isthmus, some of them exploratory, were dry.

Exploration on which the greatest hopes for success are placed by Pemex has been going on in a belt lying west of the Golden Lane and trending southeastward toward Poza Rica. Of 6 dry holes drilled in this Southern District during the year, about 4 of these were located in this belt west southwest of the Golden Lane where an oil showing was found at Soledad a couple of years ago. Two of these wells, in the Castillo area midway between Soledad and Poza Rica, are reported to have had minor showings in the Tamabra limestone. Northwest of Soledad, at Tlacolula, it was recently reported that Tlacolula No. 7 encountered an encouraging showing in porous limestone. The showings at Soledad, Castillo, and now at Tlacolula have raised hopes of another Golden Lane along this northwest-southeast belt west of the Golden Lane.

About 7 wildcat rigs were running as of the close of the year. Three are reported operating on the Isthmus, 2 in the Southern District west of the Golden Lane, and 2 in northeast Mexico.

It is reported that 15 geological, 3 gravity, and 6 reflection-seismograph parties were operating in Mexico in 1946. These crews were distributed more or less equally between the northeastern, Tampico embayment, and Isthmus areas. Pemex reports finding many structures. Exploration in Mexico has fallen short of that scheduled each year. Strikes, worn-out equipment, inadequate transportation, and high costs have materially retarded operations.

GUATEMALA

Geological exploration for oil had been going on in the northern Guatemala Peten basin in recent years; however, no work of this nature was carried on in 1946. New petroleum legislation has been drawn up but not enacted into law.

NICARAGUA

The Gulf Oil Company and the Atlantic Refining Company were reported at the beginning of the year to be preparing for a second test on the east coast in a lagoonal area. The first well, Punta Gorda No. 1, a stratigraphic test, was abandoned in February, 1945, at 6,735 feet in eastern Nicaragua. Some seismograph work is reported in eastern Nicaragua in 1946.

PANAMA

The history of exploration for oil in Panama dates back many years, and 7 wells have been drilled. The Sinclair drilled one well on the north coast near the Costa Rica border; and 2 were drilled in the adjacent area of Costa Rica. The

Gulf Oil Company obtained an oil showing in one of 3 wells drilled in the Garachine area of the south or Pacific coast. The Cities Service drilled 3 dry holes on Sinclair acreage in the Darien basin, and a well was drilled by the Carib Syndicate in the David area.

During 1946 a 20-year concession to explore and produce oil in Panama was granted the Sinclair Panama Oil Corporation, owned jointly by the Venezuela Petroleum (Sinclair) and the Cities Service companies.

Two Jersey Standard geological field parties operated during part of the year in Panama.

BAHAMAS

Exploration concessions in the Bahama Islands are held by 7 companies and encompass 48,000 square miles of land and shallow-water areas out to the 10-fathom line. All but one of these 7 groups are active in obtaining geological and geophysical data.

The Standard Oil Company (Bahamas) has been operating a gravity-meter party covering both land and submerged areas for more than a year. For the past 6 months the Standard has had a land magnetometer party in the field. At the end of 1947 the Standard will attempt a seismograph survey.

The Anglo-Bahamian (Anglo-Iranian) is presently operating a land gravity-meter party and is preparing to extend the survey into deep water. It is employing a surface magnetometer party and has begun experimenting with the seismograph.

The British Bahamas Oil Development, Ltd. (Trinidad Leaseholds and South African Mining) is covering the land and submerged areas with a gravity-meter survey using tripods.

The Bahamas Oil Company, Ltd. (Superior) is drilling on Andros Island the only deep test attempted in the area, after gravity-meter surveys were made last year and some seismograph work was done.

The Shell group is conducting a gravity survey over its concession.

The Bahamian Exploration Company, Ltd. (Gulf) has not been active up to this date but will enter into the airborne survey mentioned in the following paragraph.

Several companies holding concessions in the Bahamas will participate in a joint airborne magnetometer survey. This survey will commence in March, 1947, and will cover the entire concession area and the included ocean deeps amounting to approximately 80,000 square miles.

CUBA

Cuban production approximates about 550 barrels of oil daily from more than 200 wells. Of this, about 300 barrels of 45° A.P.I. oil is produced daily in the Jarahueco area and 200 barrels of 60° A.P.I. oil in the Motembo field. The oil comes from serpentine rock. Cumulative production of oil in Cuba approximates a half-million barrels.

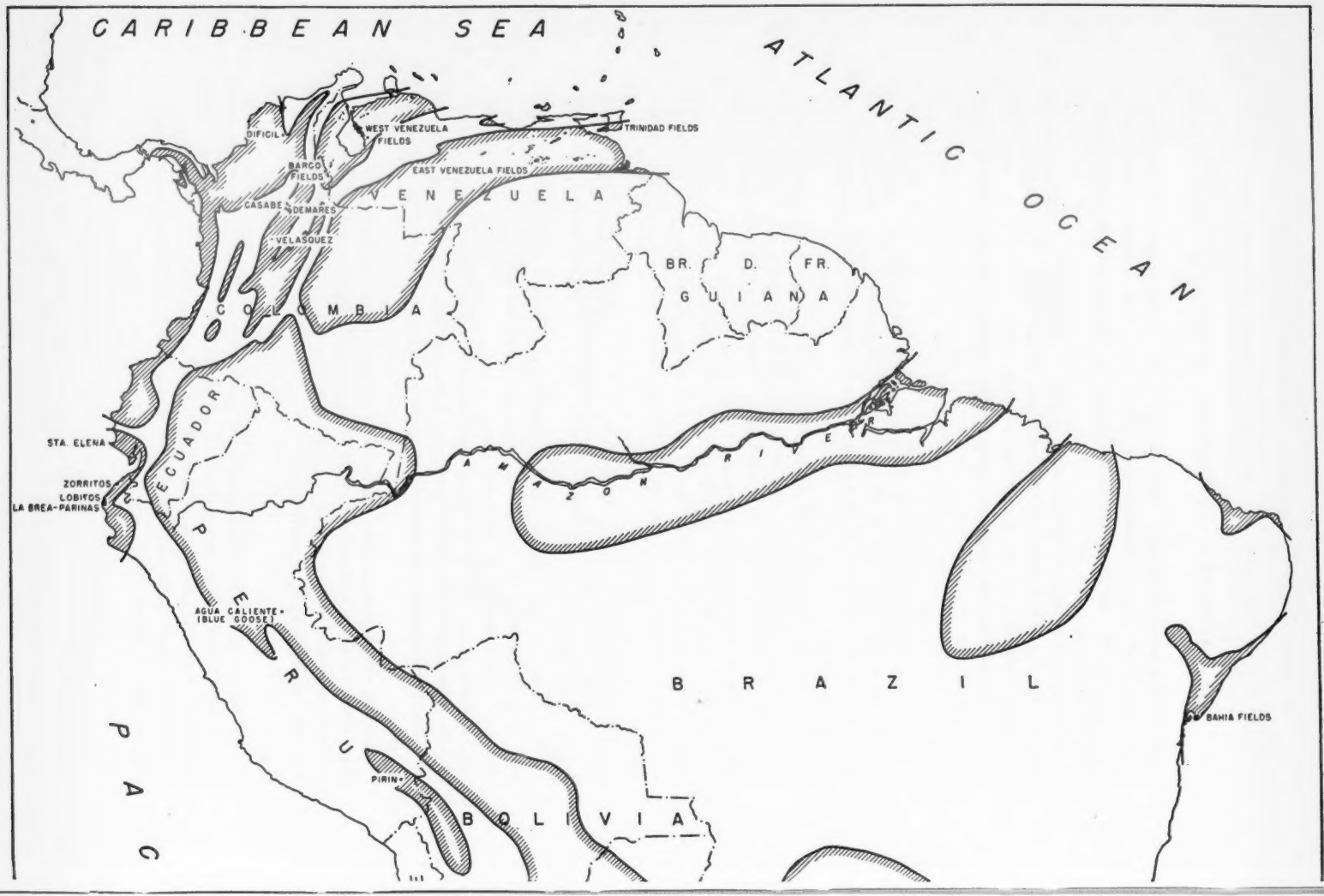

CARIBBEAN SEA
ATLANTIC OCEAN
DIFICIL
WEST VENEZUELA FIELDS
TRINIDAD FIELDS
BARCO FIELDS
EAST VENEZUELA FIELDS
VENEZUELA
CASABE
DEMARES
VELASQUEZ
BR. D. FR. GUIANA
COLOMBIA
STA. ELENA
ZORRITOS
LOBITOS
LA BREA-PARINAS
ECUADOR
AMAZON RIVER
AGUA CALIENTE (BLUE GOOSE)
PERU
BRAZIL
BAHIA FIELDS
PACIFIC
PIRIN
BOLIVIA
CAMIRI
CAMATINDI

Fig. 4

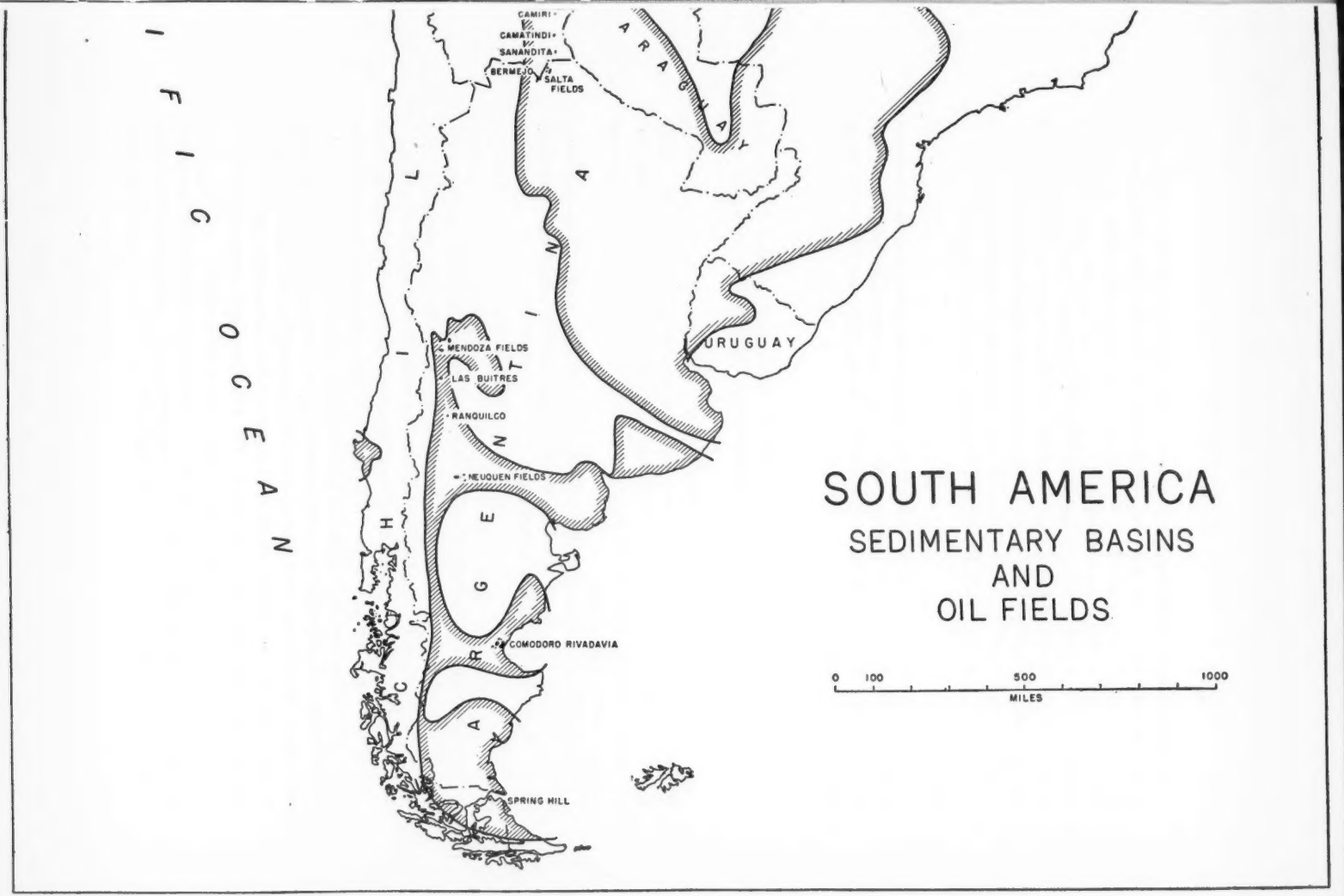

CAMIRI
CAMATINDI
SANANDITA
BERMEJO
SALTA FIELDS
PARAGUAY
URUGUAY
MENDOZA FIELDS
LAS BUITRES
RANQUILCO
NEUQUEN FIELDS
COMODORO RIVADAVIA
SPRING HILL
PACIFIC OCEAN
ATLANTIC OCEAN
ARGENTINA
CHILE
SOUTH AMERICA
SEDIMENTARY BASINS
AND
OIL FIELDS
0 100 500 1000
MILES

FIG. 4

During the year geological and geophysical exploration work was carried on in 4 different regions by the Standard Oil Company of Cuba: the Pinar basin of western Cuba (in cooperation with Atlantic), the Matanzas graben of south-central Cuba, the Matanzas serpentine belt of north-central Cuba, and the Cauto basin of eastern Cuba. The Shell-operated Estrella Company, in cooperation with Atlantic Refining, is actively exploring on the north coast of Cuba, having drilled one deep well during 1946 and started another before the end of the year.

In the Matanzas serpentine area one well was drilled and abandoned after a showing of oil had been found in the serpentine at a depth of 1,200 feet.

HAITI

In the Republic of Haiti, where exploration has been carried on for a number of years by the Atlantic Refining Company, a test is being drilled on a structure near Port au Prince that had been core-drilled during the year. Two other wells were drilled in earlier years.

SANTO DOMINGO

Exploration work carried on for 6 years in the Dominican Republic by the Dominican Seaboard, was continued during 1946. This company drilled 15 wells in the 6-year period.

In 1946, in addition to some surface geology, seismograph work was done in the Lago Enriquillo, Azua, and Cibao basins, located respectively in the southwestern, south-central, and northern parts of the Republic. A well was drilled and abandoned at 8,769 feet on an anticline in the Enriquillo basin after drilling through a thick salt section.

On the Maleno structure in the Azua basin, where a little oil was discovered in earlier wells, Maleno No. 7 is being drilled in what may be a final attempt to develop commercial production in this area.

TRINIDAD

Cumulative production of oil in Trinidad is about 328.4 million barrels. Production in 1946 ran at the rate of about 55,000 barrels daily from approximately 1,750 wells. Most of the production is from two main Miocene sands, but an increasing amount is coming from the Oligocene. All of the fields lie in the southern basin. Most of the fields are in the western part of this basin and about half of the daily yield is now coming from Forest Reserve field.

Additions to production in recent years have been largely from step-outs and field extensions. It is reported that about 23 rigs are running in Trinidad, about 8 of which are on exploratory drilling. Exploration has been spreading eastward over the southern basin in recent years. The Oligocene and deeper formations, down to include the Cretaceous, may contain additional reserves.

The Government has recently granted concessions for offshore drilling around the Gulf of Paria out to the 3-mile limit. Venezuela and Trinidad have established by treaty a common boundary across the Gulf of Paria. It may eventually develop

that these two countries will arrange to permit exploration of the entire Gulf, which separates their producing basins.

VENEZUELA

Venezuela with a cumulative production of more than 3,600 million barrels of oil ranks third after the United States and Russia in cumulative production. With an average daily output of 1,064,900 barrels of oil in 1946, Venezuela ranked second to the United States (4,747,000 barrels) and outranked Russia (450,000 barrels daily). Venezuela consumes only about 3 per cent of her total current production. Venezuela's 1946 production increased about 20.5% over 1945. About 82% of the cumulative and 69% of the 1946 daily output was from the western Venezuela fields; the balance was from eastern Venezuela. The Bolivar coastal fields contributed about 82% of the cumulative for western Venezuela and 67% of the country's total. In 1946 these Lake fields produced about 58% of the total Venezuelan output for the year. Nearly all of Venezuela's oil is produced

TABLE I

Year	*Oil*	*Gas*	*Dry*	*Total*
1940	6	—	12	18
1941	3	—	3	6
1942	6	—	4	10
1943	5	1	12	18
1944	6	—	4	10
1945	9	—	21	30
1946	10	4	64	78

from Tertiary formations. However, recent discoveries in the Cretaceous west of Lake Maracaibo may develop considerable importance.

During 1946 exploratory activity was concentrated to a large extent in evaluating large tracts of exploration-exploitation concessions which were granted by the Government during 1944 and 1945. These concessions, which total 5,131,788 hectares (12,681,000 acres), must be converted to exploitation concessions in 1947 and 1948 at which time at least 50% of the total area must be turned back to the Government as National Reserves.

Table I shows total new-field wildcat well completions from 1940 to 1946.

The large increase in wildcat drilling beginning in 1945 is due both to the end of the war and to the granting by the Venezuelan Government of large blocks of exploration concessions which must be evaluated for parcellation and return to the Government of at least 50% of the area within 3 years. This period also coincided with the active entry in Venezuela of several new companies.

The unusually high success ratio from 1941 to 1945 was due primarily to exploratory drilling having been confined to only the best prospects. The decrease in the success ratio in 1946 results from extensive drilling for stratigraphic and structural control on exploration concessions where chances of success were far below average.

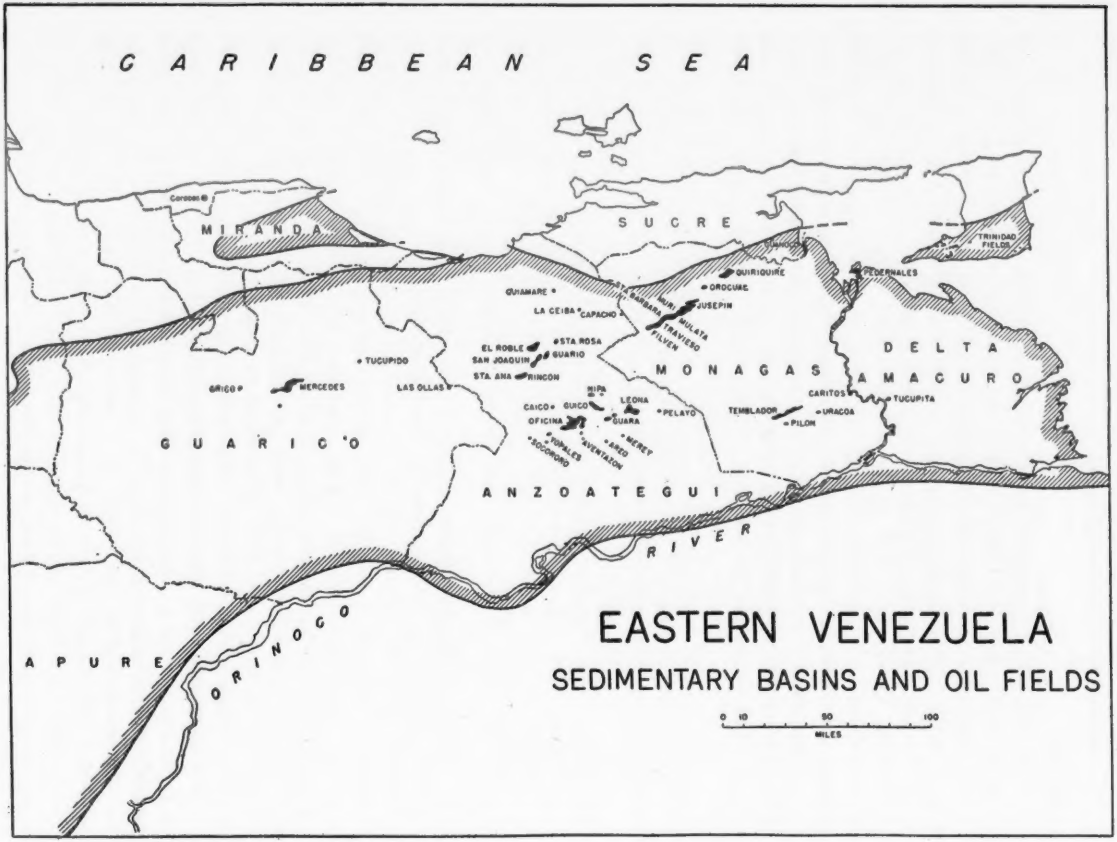

CARIBBEAN SEA
MIRANDA
SUCRE
TRINIDAD FIELDS
PEDERNALES
QUIRIQUIRE
OROCUME
GUAMARE
LA CEIBA
CAPACHO
MURI
JUSEPIN
MULATA
TRAVIESO
SILVEN
EL ROBLE
STA ROSA
SAN JOAQUIN
GUARIO
STA ANA
RINCON
TUCUPIDO
GRICO
MERCEDES
LAS OLLAS
MONAGAS
DELTA AMACURO
CARITOS
TUCUPITA
CAICO
GUICO
OFICINA
LEONA
GUARA
PELAYO
TEMBLADOR
URACOA
PILON
MERCEY
GUARICO
ANZOATEGUI
RIVER
APURE
ORINOCO
EASTERN VENEZUELA
SEDIMENTARY BASINS AND OIL FIELDS
0 10 50 100
MILES

FIG. 5

Of the 78 wildcat wells completed during 1946, 49%, or 38 wells, were located on exploration-exploitation concessions. All of these wells were unsuccessful. Of the 40 new field wildcats drilled during the year on exploitation concessions, 10 (or 25%) were successful completions.

From present indications wildcat drilling in 1947 will proceed at approximately the same rate as in 1946. During the latter part of 1947, when most of the exploration concessions are due for parcellation, fewer wells will be drilled for stratigraphic and structural control and an increase in the success ratio should follow.

Table II shows the geological and geophysical survey activity in Venezuela during 1946 in party months by states. Approximately two-thirds of this survey activity was concentrated on evaluating exploration concessions. A trend towards more comprehensive knowledge of basin structure and stratigraphy is indicated by an intensification of geological surveying of mountainous areas bordering the three principal basins of Venezuela. Geological and geophysical activity during 1947 should continue at approximately the same rate as during 1946.

TABLE II

SUMMARY OF GEOLOGICAL AND GEOPHYSICAL SURVEYS IN VENEZUELA, 1946

PARTY MONTHS

	Geological Parties	*Seismo-graph*	*Gravity Meter*	*Magne-tometer*	*Core Drill*	*Total*
Anzoategui	41	65	25	2	45	178
Apure	—	15	—	3	—	18
Aragua	5	4.5	—	—	—	9.5
Barinas	3	38	2	—	—	43
Cojedes	5	—	—	—	—	5
Delta Amacuro	—	12	8	—	—	20
Falcon	8.5	—	9	—	—	17.5
Guarico	52	102	36	9	1	200
Monagas	18	36	15.5	—	2	71.5
Sucre	3	—	1	—	—	4
Trujillo	8	8	8.5	—	—	24.5
Zulia	48	60.5	42.5	—	1	152
Total	191.5	341	147.5	14	49	743

Table III shows all fields discovered in Venezuela to December, 1946, together with names of operators, discovery dates, and methods credited with each discovery.

From the table of discovery data it will be seen that, for more than a decade exploration has been largely concentrated in Eastern Venezuela. Of the 22 fields listed in the west, only two, Mara (1945) and West Tarra (1946), were discovered within the past decade; whereas of the 40 fields discovered to date in Eastern Venezuela, 34 or all but 6, were discovered in the period 1937–1946.

Outstanding exploration successes in the year 1946 were as follows. In the state of Monagas, Eastern Venezuela, one of the most important discoveries was that of Mata Grande or West Sta. Barbara on the greater Jusepin trend. Development here has been rapid. The Travieso field, which first produced in 1946 southwest of the Sta. Barbara, is also being developed. Creole is continuing

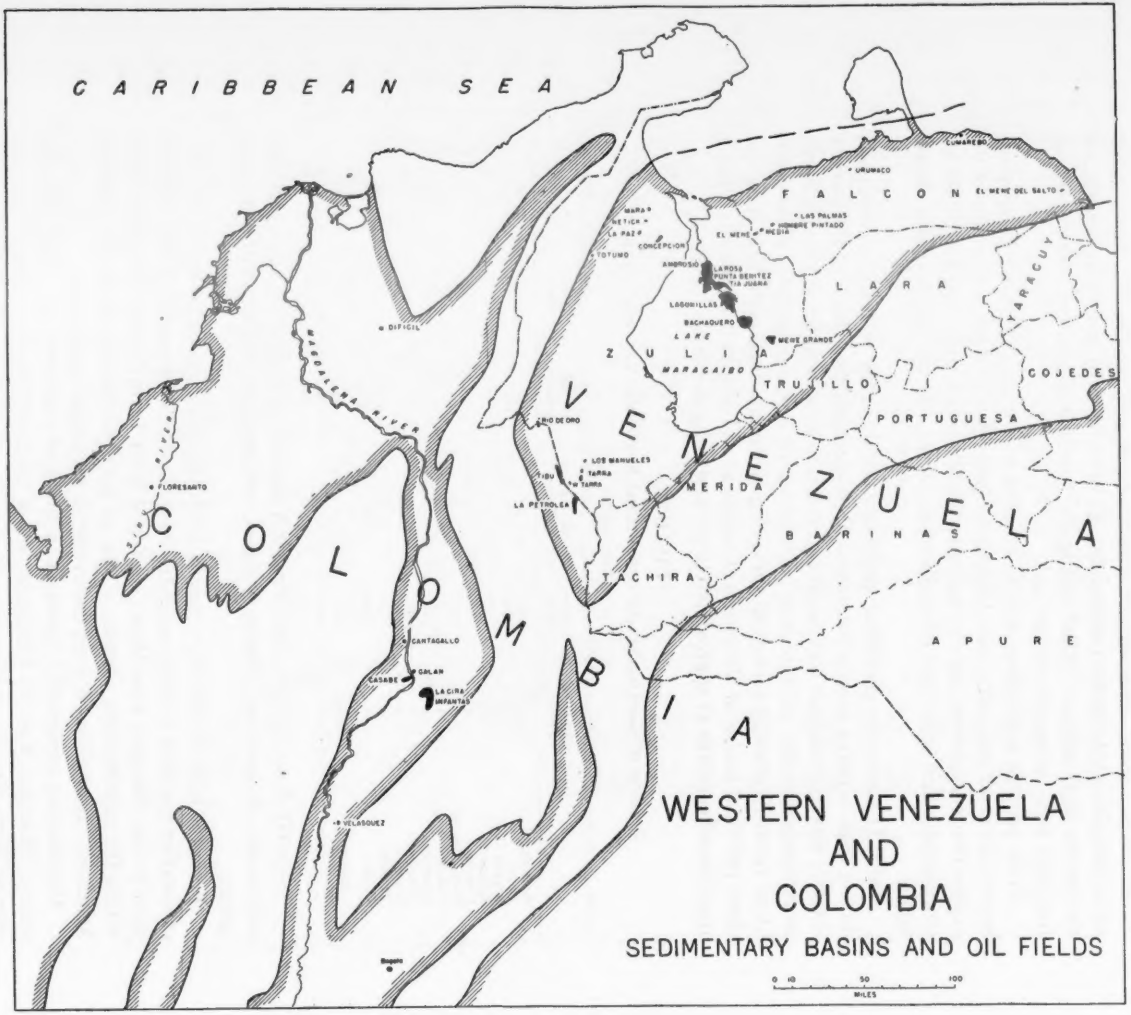

CARIBBEAN SEA
COLOMBIA
VENEZUELA
FALCON
LARA
ZULIA
LAKE MARACAIBO
TRUJILLO
COJEDES
PORTUGUESA
MERIDA
BARINAS
TACHIRA
APURE
YARACUY
EL VIGIA
URUMACO
EL MENE DEL SALTO
LOS PALMAS
HOMBRE PINTADO
EL MENE
MEDIA
MARA
METICK
LA PAZ
CONCEPCION
TOTUMO
AMBROSIO
LA POSA
PUNTA BENITEZ
PUNTA JUBAK
LAGUNILLAS
BACHAQUERO
MENE GRANDE
DIFICIL
MAGDALENA RIVER
RIO DE ORO
LOS MANUELES
TARRA
TARRO
TIBU
LA PETROLEA
FLORESANTO
CANTAGALLO
GALAN
CASABE
LA CIRA
INFANTAS
VELASQUEZ
Bogotá
WESTERN VENEZUELA
AND
COLOMBIA
SEDIMENTARY BASINS AND OIL FIELDS
0 10 50 100
MILES

FIG. 6

TABLE III

DISCOVERY DATA, VENEZUELAN OIL FIELDS

Area and Field	Operator	Year of Discovery	Methods of Discovery
		WESTERN VENEZUELA	
ZULIA			
Bolivar Coastal field	Creole-Meneg-Shell	1917	Drilling near surface indications of oil
Mene Grande	Shell	1914	Drilling near surface indications of oil
Los Barrosos	Creole	1922	Drilling near surface indications of oil
Misoa	Creole	1921	Drilling near surface indications of oil and surface geology
Concepcion	Shell	1925	Surface geology
La Paz	Shell	1925	Surface geology
Los Manueles	Shell	1927	Surface geology
Rio de Oro	Shell	1915	Drilling near surface indications of oil
Tarra	Shell	1916	Drilling near surface indications of oil
West Tarra	Shell	1946	Surface geology
Totumo	Ven. Govt.	1914	Surface geology?
Amana	Guasare Oil Co.	1928	Surface geology?
Netick	Orinoco Oil Co.	1929	Surface geology
Mara	Shell	1945	Seismograph and structural core drill
FALCON AREA			
Cumarebo	Creole	1931	Surface geology
Mene de Acosta	North Ven. Pet.	1927	Surface geology
Mene de Mauroa	British Cont. Oilfields	1921	Surface geology
El Mamon	Coro Pet. Co.	1928	Surface geology
Las Palmas	Creole	1928	Surface geology
Monte Claro	Creole	1926	Surface geology
Hombre Pintado	British Cont. Oilfields	1927	Surface geology
Media	British Cont. Oilfields	1929	Surface geology
		EASTERN VENEZUELA	
NORTHERN MONAGAS AREA			
Pedernales	Creole	1933	Drilling on surface indications of oil
Guanoco	Bermudez	1913	Drilling on surface indications of oil
Quiriquire	Creole	1928	Drilling on surface indications of oil
Orocual	Creole	1933	Drilling on surface indications of oil
Jusepin	Creole	1938	Seismograph and regional geology
Mulata	Creole	1941	Subsurface geology
Sta. Barbara-Muri-Travieso-Avipa	Consolidada-Meneg-Atlantic	1941	Subsurface geology
West Travieso	Phillips-Meneg	1946	Seismograph core drill and subsurface geology
Capacho	Creole	1945	Seismograph core drill and subsurface geology
SOUTHERN MONAGAS AREA			
Temblador	Creole	1936	Seismograph
Pilon	Creole	1936	Seismograph
Uracoa	Creole	1937	Seismograph
Los Caritos	Texas	1940	Seismograph
Tucupita	Texas	1945	Seismograph
NORTHERN ANZOATEGUI AREA			
La Ceiba	Meneg	1946	Surface geology and seismograph
Sta. Rosa	Meneg	1941	Surface geology and seismograph
San Joaquin-Guario	Creole-Socony	1940	Surface geology and seismograph
El Roble	Creole	1939	Surface geology and seismograph
Santa Ana-Rincon	Meneg-Texas	1937	Surface geology
Quiamare	Meneg	1942	Surface geology
SOUTHERN ANZOATEGUI AREA			
Caico Seco	Meneg	1946	Seismograph and core drilling
West Nipa	Meneg-Socony	1945	Seismograph and core drilling
East Nipa	Meneg	1946	Seismograph and core drilling
GM-4	Meneg-Socony	1946	Seismograph and core drilling
West Guico	Socony	1946	Seismograph and core drilling
West Guara	Meneg-Socony	1941	Seismograph and core drilling
East Guara	Meneg	1942	Seismograph and core drilling
OS-31	Meneg	1946	Seismograph adn core drilling
OG-202	Meneg	1941	Seismograph and core drilling
Oficina	Meneg	1937	Seismograph
Aventazon	Meneg	1942	Seismograph and core drilling
Yopales	Meneg	1937	Seismograph and core drilling
Socororo	Creole	1940	Seismograph and surface geology
Leona	Meneg	1938	Seismograph and surface geology
Pelayo	Atlantic	1946	Seismograph and gravity meter
Areo-Merey	Meneg	1937	Seismograph
GUARICO AREA			
Las Ollas	Creole	1942	Seismograph
Las Mercedes	Texas	1942	Seismograph and surface geology
Grico	Texas	1946	Seismograph
Tucupido	Atlantic	1946	Seismograph

FIG. 6

exploratory drilling of the area between Jusepin and Quiriquire. About 20 exploratory wells were drilled in Monagas during the year and about 6 others were drilling at the end of the year.

Of 11 wells drilled in Anzoategui in 1946, 5 discoveries were made, including the Nipa field which was found around the close of 1945, about 20 kilometers north of Oficina. Other discoveries include Meneg's GM-4 (South Guico), 10 kilometers north of Oficina; Caico Seco, 30 kilometers northwest of Oficina; Pelayo on the Oficina-Guara-Leona trend; and La Ceiba, 35 kilometers east of San Mateo. The Texas Company's Tucupito field in Delta Amacura, discovered in 1945, started shipping oil in 1946.

In the state of Guarico there was considerable activity in all phases of geological, geophysical, and drilling exploration. About 19 wells were drilled, resulting in 3 discoveries. About 10 wells were drilling at the close of the year. The Texas Company discovered the Las Mercedes field in 1942, since which the field has been considerably extended by drilling. This oil is awaiting pipeline connection northeastward to the coast. During 1946, The Texas Company made a discovery at Grico, 40 kilometers west of Mercedes field, and the Atlantic discovered the Tucupido field on Pantepec acreage about 65 kilometers northeast of Mercedes.

In the state of Zulia, western Venezuela, a probably important discovery is that of the Colon Development Company (Shell) at West Tarra in the district of Colon southwest of the lake. Oil was discovered here in late 1946 in the Cretaceous wherein production is also obtained in the Barco Concession of Colombia farther southward in the same basin. The older fields in the Colon district (Tarra, Rio de Oro, *et cetera*) produce from the Eocene, which is also productive in the Barco. The developments at West Tarra, together with the discovery in 1945 of high yields in fractured limestones of the Cretaceous by deeper drilling on the old La Paz field southwest of Maracaibo, and again at Mara in the same year, has aroused considerable interest in Cretaceous prospects in the western Maracaibo basin area.

About 18 kilometers east of Lake Maracaibo, Shell's Curacao 2a had reached a depth of 15,100 feet, where it was bottomed in the Eocene around the close of the year. This is the deepest well drilled in South America. Among other tests of interest is one being drilled by the Creole for the Shell in 90 feet of water in the northwestern part of the lake at a point about 7 kilometers out from the productive limits of the Lake field of Tia Juana.

More than 5 million concession acres are held in the Apure, Barinas, and Tachira areas of the southwest Venezuela basin, sometimes referred to as the Apure basin. The main reason for delay in exploring this basin seems to be its relative inaccessibility. The Socony-Vacuum is the principal operator active here. Three dry holes were completed in 1946 and another well was drilling at the close of the year.

COLOMBIA

Cumulative oil production in Colombia totals about 388 million barrels. 1946 production was at the rate of around 64,276 barrels daily. About 85% of the current production is coming from the Magdalena Valley and the remainder from the Barco area. At present the most important producing fields are La Cira, Casabe, La Petroleo, Infantas, and Tibu in approximately the order named. The first two and the fourth are in the Magdalena Valley; the other two are Barco fields. Fields found from 1940 on are: Tibu, 1940; Casabe, 1941; Cantagallo, Floresanto and El Dificil in 1943; Galan, 1945; and Velasquez in 1946. Of these fields, Tibu is in the Barco; Casabe, Cantagallo, Calan, and Velasquez are in the middle Magdalena Valley; Floresanto lies in the Sinu Valley in the western part of the north coastal basin; and El Dificil is in the lower Magdalena part of the coastal basin.

After the end of the European conflict in 1945, exploration activities in Colombia were considerably accelerated by expectation of new and more favorable petroleum legislation in the near future. Due to growing uncertainties about the terms on which new concessions would be granted, the activity in 1946 was not markedly greater than in the previous year, and some operators were curtailing expenditures.

During 1946, the principal companies engaged in exploration work were: the Gulf, Richmond, Shell, Socony, Texas, and Tropical. Geological work was carried out by one or more companies in nearly every one of the important sedimentary basins, including the Magdalena River Valley, the Barco sector of the Lake Maracaibo basin, the Caribbean coastal region, the Llanos plains east of the Andes, the Caqueta-Putumayo region along the Peruvian frontier and the Pacific Coast basin. Geophysical work during the year was confined to the first five regions mentioned, a large proportion of which was in the Magdalena Valley and the Llanos plains area. In December, 1946, it was estimated that 25–30 geological, 10 seismograph, and 8 gravity-meter parties were in operation by the industry.

Each of the six principal operating companies were drilling on 2 or more wildcats in 1946. Out of approximately 16 important wildcats terminated during the year, only one, The Texas Company's Velasquez 1, in the middle section of the Magdalena Valley, was a discovery well.

In the southwestern part of the Llanos, the Shell has completed 5 tests at Chafurray and has started a third test at San Martin, which was drilling ahead at 6,306 feet at the end of the year. About 150 kilometers northeast of San Martin, the Tropical Oil Company has recently started an exploratory test near the Meta River.

Tropical Oil Company completed 5 producers and abandoned 2 wells on the Colorado structure; it also completed 52 producers of various sizes in the Infantas-La Cira area of the De Mares Concession in the Middle Magdalena Valley, making an average daily production on the concession of 35,760 barrels, a decrease of 16.7% from last year. The Shell Company completed 7 new wells, 4 of

which were producers, on its Dificil structure, located in the Lower Magdalena or Caribbean coastal region. The Dificil field is still closed in because of lack of pipeline facilities. In the Casabe field, in the Middle Magdalena Valley, it completed 17 producers with no dry holes, the daily production rate having reached by the end of the year a figure of 12,500 barrels. In the Barco Concession, the Colombian Petroleum Company completed 9 producers and 1 dry hole in its Tibu area; 4 other wells were being tested at the end of the year. The gross production for the Barco Concession during 1946 was 6,198,175 barrels, an increase of 658,000 barrels over the previous year.

ECUADOR

During 1946 the International Ecuadorean Petroleum Company practically completed its extensive search for oil in the Pacific slope sector of Ecuador. Geological and geophysical activities were carried on in the northern, southern, and west central portions of this region. Two wildcats were completed in the north, 1 in the west along the coast, and 3 in the southern basin, south and west of Guayaquil, 1 of which reached a depth of 13,206 feet; all 6 tests were dry. At the end of the year the I.E.P.C. had started its twentieth and last wildcat well in the west-central part of the country and had terminated all other exploration activities.

The Shell Company has a concession of 25,000,000 acres east of the Andes Mountains in Ecuador and carried on geological field work on a limited scale and a geophysical survey which included two seismic parties at the close of the year. They completed one wildcat as a dry hole and started another during 1946.

Production on the Santa Elena Peninsula was about 6,500 barrels per day at the end of the year, about three-fourths of which was from the Ancon field. Ten wells were completed as small producers in 1946. Cumulative production to the end of 1946, all from the Santa Elena Peninsula, was about 38.9 million barrels.

PERU

Peruvian production began humbly back in 1860, has been continuous since 1884, and increased steadily from the latter date to a peak of about 48,000 barrels daily in 1936, and has since declined to a daily yield of about 34,150 bbls. in 1946. Current production is approximately distributed as follows: La Brea y Parinas Estate, 84.5%; Lobitos area, 13%; Zorritos area, 1%; Agua Caliente, 1.5%. The first three producing areas lie along the coast of northwest Peru; the Agua Caliente field was discovered in the large basin east of the Andes in 1939. Peru has produced a total of about 343,350,000 barrels to the end of 1946.

Anticipating the passage of legislation which would permit exploration and exploitation operations on the east side of the Andes in Peru, several major companies started preliminary geological studies of that region in 1945 and 1946. The Shell, Socony, and International Petroleum Company each had several geological parties in the field during the 1946 field season. Because of the high exploration

costs and the realization that development expenditures will be on a stupendous scale, it is probable that interest in this region will shortly decrease unless encouraging legislation is enacted soon.

One small field on the Agua Caliente structure of the Cia. Ganzo Azul is now producing on the east side of the Andes. Discovered in 1938, 9 wells have been drilled, the last producer being completed in 1946. Drilling had been suspended from 1941 to 1946. A 500-barrel-capacity skimming plant processes this 44° A.P.I. crude for the local market. Since the market for the oil is confined entirely to the sparsely populated region drained by the headwaters of the Amazon, production has been limited to about 400 barrels per day. The field is reported to have a potential of about 1,800 barrels daily. It is located near the Ucayali River at about 9° S. Lat.

During the latter part of 1946, 2 wildcat wells were in process of drilling or preparation to drill in eastern Peru. Both of these are located on the Ucayali tributary of the Amazon River at about 7° S. Lat., one being drilled by the Peruvian Government and the other by a Peruvian private company.

On the Pacific Ocean side of the Andes the exploration activities were confined to wildcat wells in the vicinity of the producing fields, in northwestern Peru. The International Petroleum Company drilled 94 wells during the year, of which 29 were substantially wildcats. Of the total of 94 wells completed on the La Brea-Parinas Estate, 55 produced oil and 3 produced gas, with 36 dry holes. At the end of the year 10 exploration and 12 development wells were being drilled and 1 well was being carried deeper.

The Lobitos and El Alto oil fields of the Compania Petrolera Lobitos are immediately north of the La Brea-Parinas Estate. During 1946 there were 87,206 feet of hole drilled and 35 wells completed, all of which were producers. Production is maintained between 6,000 and 7,000 barrels per day.

The Zorritos property was operated privately until 1930 when it was purchased by the Peruvian Government. Production has been about 380 barrels daily. There have been no reports of new developments covering operations in this area for 1946.

CHILE

The major oil prospects of Chile are in the Magallanes area at the southern end of the country. It is here that most of the exploration activity in Chile has been carried on periodically in the past 20 years. Previous to recent years about 8 relatively shallow wildcat wells had been drilled in or close to the foothills belt on Brunswick Peninsula and Isla Riesco without obtaining more than minor oil or gas showings.

Several years ago geological work was initiated for the account of the government by Glen Ruby and has been continued by the United Engineering Corporation, S.A., and the United Geophysical Corporation, S.A. A field discovery was made in 1945 by the first well drilled on the Springhill seismograph structure in

the northern plains of the Island of Tierra del Fuego near the Straits of Magellan.

The discovery well at Springhill has been estimated at about 700 barrels per day on a ¼-inch choke. The oil is of 39° A.P.I. gravity. No. 2, a dry hole was drilled down on the nose of the structure. No. 3, which was higher structurally than No. 2, came in as a gas and oil well. No. 4, recently completed as a dry hole, appears to have been drilled off structure. Considerable drilling will probably be needed to fully determine the nature of the structure and the size of the pool.

This southern basin of Chile and adjoining parts has a maximum of 15,000–20,000 feet of Upper Cretaceous, about 12,000 feet of Lower Cretaceous, probably Upper Jurassic and a variable thickness of Tertiary. The oil at Springhill occurs in a sand which lies in beds of as yet undetermined age beneath an unconformity overlapped by Lower Cretaceous.

Three geologists, a paleontologist and a seismograph crew were working in the Magallanes basin in 1946. It is reported that two more rotary rigs have been ordered. A string of cable tools is engaged in drilling foothills structures. Four wells have been drilled on such structures during the recent years, so far without result. There are considerable thickness and facies changes between the foothills and the plains.

ARGENTINA

Argentina's cumulative production amounts to about 364 million barrels. Daily average production has been running at about 57,000 barrels from approximately 3,600 wells. The production is equivalent to about three-fifths of the country's consumption. Of this daily yield about 69% is Upper Cretaceous production from the Comodora Rivadavia district of southern Argentina; 15% is late Triassic oil from the North Mendoza basin of west central Argentina; 10% is Jurassic production from the Plaza Huincul area of the Neuquen basin, also in west-central Argentina, south of Mendoza; and 6% is largely from Permo-Carboniferous sedimentary rocks in the Salta foothills area of northern Argentina.

About 65% of the oil production comes from the Government-owned fields operated by the Yacimientos Petroliferos Fiscales. For many years expansion by private companies has been practically impossible due to government restrictions on acreage acquisition, *et cetera*.

Due largely to lack of materials during the war, wildcatting in Argentina has decreased from about 90 wells drilled in 1940 to 17 in 1945 and an estimated 12 in 1946. Most of the wildcats in recent years were located in the Comodoro, Nequen, and Mendoza areas. However, there has been some exploratory drilling in the Chaco and Salta areas of north Argentina and in the Santa Cruz basin of southern Patagonia. A number of structures have been outlined during the war years, and as materials are available these will be tested. It is anticipated that the annual number of wildcats drilled will have increased to about 60 by 1950.

No new fields were discovered in the past 2 years. In 1943 the major Challaco field was discovered east of Plaza Huincul in the Neuquen basin and another

minor field was found in the same basin in that year. In 1944 a major field was found at Caleta Olivia near the coast in the southern part of the Comodoro basin, and a small field was discovered in the same year at Punta Piedras in the Comodoro basin.

BOLIVIA

Cumulative oil production in Bolivia amounts to about 3,480,000 barrels. Daily production comes from 25 wells and now amounts to about 1,000 barrels, approximately one-third of which comes from each of the Camiri, Sanandita, and Bermejo fields in the eastern Bolivian foothills. Oil from the last two named fields is largely exported to Argentina.

The Bolivian Government owns the industry. Its operating organization, Yacimientos Petroliferos Fiscales Bolivianos, is reported to plan exploratory drilling on the Guariri and Mandiapecua areas previously explored by private capital. If results are disappointing it is reported that further drilling of exploitation wells will be done on the less accessible Camatindi structure, which was also drilled and found oil-bearing by private capital prior to expropriation. All these areas lie in the eastern Bolivian foothills of the Andes.

Plans were announced for the building of a 6-inch pipe line from the Camiri area 255 miles westward toward the center of population around Cochabamba, and also for the expansion of refining capacity along with that of production. To provide adequate production to support the pipe line and also to provide funds for an industry that has long been operating at a deficit, Y.P.F.B. contracted in in March to drill 50 wells on the Camiri structure.

PARAGUAY

Exploration for oil in Paraguay had received little active attention prior to that of the Union Oil Company of California, which several years ago acquired a concession to explore for petroleum in an area of about 23 million acres in the Paraguayan Chaco. The Chaco of Paraguay is a largely brush-covered plains area which spreads westward from the Paraguay River toward the Andean foothills, and under which Paleozoic formations lie beneath a cover of younger, largely continental sedimentary rocks.

The first test well and, incidentally, the first well drilled for oil in Paraguay was drilled to the total depth of 7,579 feet. It was located in the southwestern part of the Paraguayan Chaco at a water hole called Santa Rosa, about 40 miles from the Bolivian border and 255 miles west of Puerto Casado on the Rio Paraguay. No showings of oil were encountered, but the well served its purpose in supplying information on the section.

Location for a second well will be announced soon, based on results of geophysical studies. Future plans call for the continuation of geophysical work by two or more seismic crews, and the drilling of additional test wells in widely scattered parts of the Chaco.

BRAZIL

Brazil covers about 47% of the South American continent. Her annual petroleum requirements approximate 10 million barrels, nearly all of which is imported. Potential crude production of about 3,000–4,000 barrels daily is all developed on several small structures in the small Bahia basin on the east coast. Actual production during 1946 averaged about 200 barrels daily, as most of the wells are shut in due to lack of refining capacity. Cumulative production amounts to about 258,000 barrels.

About 86 wells have been drilled in the Bahia graben basin since oil was first discovered there in 1939. Of these wells about 30 are classed as oil wells and 14 as gas wells.

The Bahia basin has a maximum of about 10,000 feet of sediments ranging in age from Tertiary to Lower Cretaceous or possibly Upper Jurassic age. The oil occurs in Cretaceous sands in faulted structures.

Most of the potential production is represented by 3 wells completed in 1946 on the Candeias structure where production is spotted. Other fields include: Lobato-Joanes, where 5 producers out of 17 wells drilled have a potential of 85 barrels; Itaparica, in the bay on the north end of an island of the same name, where 9 oil and 7 gas wells out of 24 wells drilled have a potential of several hundred barrels; and Aratu, where, out of 13 wells drilled, 2 are classed as small oil wells and 7 as gas wells. Tests have been drilled on several other structures. It is reported that about 7 rigs are operating in the Bahia area.

The geological work in the Bahia region is being directed by the firm of De Golyer and MacNaughton and drilling is under contract to J.E. Brantly's Drilling and Exploration Company. The United Geophysical Corporation reports that one of their seismograph crews has started a survey in the state of Paraná in the large basin of the same name in South Brazil, and another crew has commenced seismograph work on the large island of Marajo at the mouth of the Amazon.

Study of structure from aerial photographs taken during the war over the Piauhy-Maranhao basin of northeast Brazil is reported. The sediments of this area have been generally considered to be mainly continental in facies, though the recent discovery here of a Devonian marine fauna is of paleogeographic and stratigraphic interest.

All work carried on in Brazil is for the account of the Government under the supervision of the National Petroleum Council. A newly revised Brazilian Constitution was approved in September which now enables the enactment of legislation permitting foreign capital to participate in Brazilian companies; but a new Petroleum Law has not yet been promulgated.

EASTERN HEMISPHERE

GREAT BRITAIN

Cumulative oil production in the British Isles totals about 3,500,000 barrels. Current production is 1,200 barrels daily from about 235 wells in 6 fields, principal

of which are Eakring with its Dukes Wood extension, and Kelham and Caunton, also in the Eakring area of Nottinghamshire in the Midlands. The oil in all fields comes from the Millstone Grit of Bendian or Pottsville age, except for the small Formby field in Lancashire on the northwest coast where the small production comes from the upper Triassic. A minor amount of oil is being produced from a structure drilled in Midlothian, southeastern Scotland.

Some drilling for oil had been done in England as early as the first World War. A small showing was obtained in a well drilled at Hardstoft in the Midlands in 1918. Search on an extensive and systematic basis really began in 1934 with the passing of the Petroleum Production Act of that year. The D'Arcy Exploration (Anglo-Iranian), Anglo-American Oil Company (New Jersey Standard group), Gulf Exploration (Britain) and Steel Brothers and Company, Ltd. were the most active operators. Since 1941 only the two first-named operators continued the search. The main areas of activity were southern England and, later, northern England and southeast Scotland and the English Midlands.

Eakring was discovered in 1939 as a result of combined geological and seismic surveys. As a result of geophysical surveys, Kelham Hills was discovered in 1940, and Caunton and Dukes Wood in 1943. Formby was found by drilling on surface seepages. The small Midlothian field in Scotland was discovered by drilling on a surface structure in 1937. Search has been carried on actively through 1945 and 1946. Six holes were drilled in 1946 in Midlothian, Scotland, Yorkshire, Nottinghamshire, Dorsetshire, and Lincolnshire. Seismic and gravity surveys were also continued during the year in these and other areas of north England. In 1946 interest in south England was again renewed by filings on prospective licenses over the Salisbury Plain and Isle of Wight, and by the carrying on of geological and geophysical work. Interest in south England was largely centered on the Mesozoic, that of north England on the Carboniferous.

FRANCE

Cumulative oil production in France, amounting to more than 14 million barrels, has almost entirely come from the Pechelbronn area in Alsace in the Rhine graben discovered in 1882. Production prior to the war of about 1,350 barrels daily is reported to have declined to about 1,100 barrels in 1946.

While the French Government had participated in the search for oil in her territories of North Africa and elsewhere little attention had been given to the homeland. In 1937 a government petroleum research department was created for oil exploration in France. Two tests in the Aquitaine (Bordeaux) basin of southern France at the north foot of the Pyrenees resulted in the discovery of gas in the Cretaceous at St. Marcet in 1939 and some oil in Jurassic limestone in 1940. This field was developed by a 100% Government-owned company (Regie Autonome des Petroles). At the end of 1946 it had 6 producing and 5 shut-in gas wells, 1 oil well producing 18 barrels per day, and 1 well drilling. Gas production was 10 million cubic feet daily. Drilling along the trend southeast shows indications

FIG. 7

of bringing in another gas field. Drilling on other folds is in progress. Altogether, 5 rigs were in operation near the end of the year on the 495,000 acre concession of Regie Autonome.

Two other Government-sponsored companies with some private capital have large concessions in the same basin. The Societe Nationale des Petroles d'Aquitaine (SNPA) holds nearly 6 million acres in a block surrounding the Regie Autonome concession. The block extends about 60 miles northward from the front of the Pyrenees and about 190 miles eastward from the Atlantic coast. A second company, the Societe Nationale des Petroles du Languedoc Mediterranee (SNPLM), holds a concession of about 2 million acres along the Mediterranean in the Montpellier area.

Neither of these companies has developed any production to date, but they are actively exploring their concessions by geology, geophysics, and core drilling. In addition, at the close of 1946, SNPA had 4 deep tests drilling, and SNPLM was drilling 3 deep and 2 shallow tests.

The old producing field at Gabian, north of Beziers lies in the SNPLM concession. Fifteen shallow wells were at one time productive on this field from the Triassic. At present only 5 wells are producing a monthly total of 90 barrels. This field has produced 186,250 barrels in 20 years.

NETHERLANDS

Though traces of oil were observed in borings in eastern Netherlands in the early 1920's little attention was given to them until exploration was started in north Germany in 1930. From 1930 to 1939, or prior to World War II, 12 shallow exploration wells were drilled in the northern and eastern part of the Netherlands. While no oil was found, these wells gave considerable data on the subsurface complexities of structure and overlap in a section whose main prospects are in the Mesozoic and Permian.

After their occupation in May, 1940, the Germans showed an interest in finding oil because of showings obtained in Germany on a structure that continued across the frontier into the Netherlands. Also by 1943, two small oil fields had been developed on the German side. By the close of the war, the Germans had covered a large area in the Netherlands with gravity and seismograph surveys.

In 1943 oil was discovered in the Netherlands at Coevorden in the Valendis (early Cretaceous) and in the Lias. Development proceeded and production increased from 1,400 barrels in 1943 to 41,000 barrels in 1945. Production in the Coevorden field is currently about 2,500 barrels daily. Cumulative oil production has attained about 480,000 barrels. Gravity parties and a core rig were at work at the beginning of 1947, but no exploratory work was in progress.

GERMANY

There has been an over-all rather gradual increase in German oil production since its very humble beginning in 1874, with the most rapid increase taking place

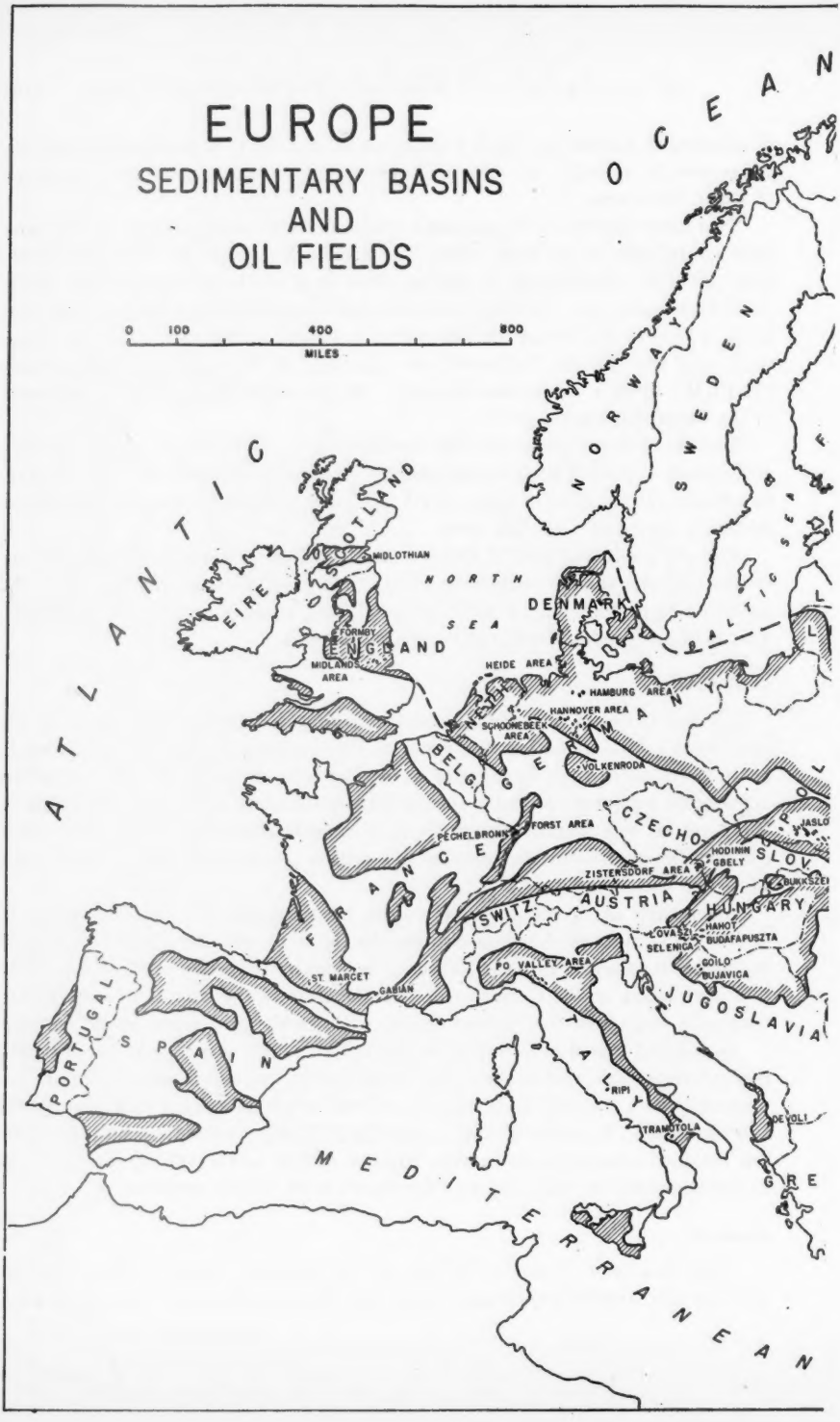

EUROPE
SEDIMENTARY BASINS
AND
OIL FIELDS
0 100 400 800
MILES
ATLANTIC OCEAN
NORWAY
SWEDEN
BALTIC SEA
SCOTLAND
EIRE
NORTH SEA
DENMARK
ENGLAND
MIDLOTHIAN
FORNOY
MIDLANDS AREA
HEIDE AREA
HAMBURG AREA
HANNOVER AREA
SCHOONEBEEK AREA
NETHERLANDS
BELGIUM
VOLKENRODA
PECHELBRONN
FORST AREA
CZECHO SLOV
HODININ
GBELY
ZISTERSDORF AREA
FRANCE
SWITZ
AUSTRIA
HUNGARY
HAMOT
LOVASZI
BUDAFAPUSZTA
SELENICA
GOILO
DUJAVICA
ST MARGET
CABIAN
PO VALLEY AREA
JUGOSLAVIA
PORTUGAL
SPAIN
ITALY
RIPI
TRAMUTOLA
MEDITERRANEAN

FIG. 8

IZHMA
KOZHVA
UST-UKHTA
CASPIAN MOUNTAINS
KAMA RIVER AREA
IVANOVA
TUIMAZY
ISHIMBAEVO AREA
BUGURUSLAN
KINEL
KUIBISHEV
BUZLUK
SYZRAN
YABLONOVI
AKTIUBINSK
PENZA
DSHAKSMAI
SHOBANKUDUK
EMBA AREA
ROMNY
POLTAVA
KASHKARA
BORYSLAW AREA
BITKOW AREA
CRIMEA AREA
KUBAN AREA
GROZNY AREA
MAIKOP AREA
DAGHESTAN AREA
BACAU AREA
SIAZAN
CAPE KILIAZIN
BAKU AREA
PLOESTI AREA
BATUM AREA
TIFLIS AREA
PIRSAGET
DUROV DAG
BLACK SEA
CASPIAN SEA
ESTH.
TVIA
TH.
BULGARIA
SEA

in the 1930's. In a review of the development of the German oil industry, four phases stand out.

1. From first production in 1874 to 1930 only 5 fields existed and the daily rate did not exceed 2,000 barrels.

2. In 1934 the industry was stimulated in preparation for war, by nationalization of lands to facilitate the granting of concessions, and by subsidized exploratory drilling. The percentage of wildcat wells increased from 35% of total drilling in 1933 to 54% in 1937. In 1935 many new fields began coming in, and the over-all production rate increased.

3. In 1939, after about 10 new fields had been found, rigs were pulled off exploratory drilling and placed in the proved fields so as to further increase production. This went well for 1940, the peak year of 20,300 barrels per day average, but the next 2 years showed decreases and some fields were obviously gutted.

4. In an attempt to keep production to the former level, more rational production methods were practiced between 1943 and 1945.

Cumulative production amounts to about 85 million barrels. Production in 1946 was at a daily rate of about 12,500 barrels.

Oil-finding in Germany shows a poor record because of low discovery rate and small finds, generally averaging less than 1,000,000 barrels ultimate. Of the 900 exploration wells drilled during the period of subsidy (1934–1945), only 23, or 2.5%, of them were discoveries. During the time of actual war (1939–1945) there were 421 exploratory wells and 10 (2.4%) discoveries.

Close to 65% of Germany's cumulative production was obtained since 1935. During this period about 28 oil fields were discovered. About half of these fields are in the central Hannover area or region of the old Nienhagen field. Though 11 fields were discovered since 1940 production declined to about 10,500 barrels daily in 1945. Most of this decrease appears to have been the result of aerial bombing and poor production practices.

Nearly all of German production has come from Lower Cretaceous and Jurassic formations on the flanks of broken salt structures in northwest Germany. Reitbrook, discovered in 1937 in the Hamburg area, is the only important field found on the many deeper domes explored.

No important additional discoveries have been made in the Zechstein (Permian) dolomites in the Thuringian basin since the discovery of Volkenrode, in 1930. However, in Schleswig-Holstein near the Danish border, the Heide field, discovered in 1939 in the vicinity of old production first recovered in shallow diggings as early as 1856, produces from above and below a Mesozoic overlap on Permian dolomitic limestones on the flank of a salt structure.

Three fields were discovered in 1942 and 1943 in West Hannover, near the Netherlands frontier in early Cretaceous beds. As stated in the remarks on the Netherlands, the activities in west Hannover led to the discoveries in the adjacent Coevorden area in the Netherlands.

An enormous amount of gravity and seismic work was done before and during

the war, and an active program undoubtedly will be resumed. The trend of development in the immediate future is expected to focus on the Dutch borderland area where it appears that the non-salt structures may furnish relatively good production. Also, it is expected that there will be a search for accumulation under new conditions such as may be present in the salt basin between the known domes and ridges as well as deeper flank production.

The oil fields and refineries of Germany are nearly all in the British zone of occupation in northwest Germany. Their operation falls under the Military Government which exercises its supervision through the North German Oil Control. The companies which were operating in northwest Germany prior to the war are preparing to continue the operation of their properties. It was reported late in 1946 that the Oil Control was requesting the Military Government to permit the hiring of two American reflection crews. Under the proposed plan any prospects found would be leased to companies now operating in Germany. The Seismos Company of Hannover, once one of the largest geophysical companies in the world, was operating four crews in the Hannover basin in 1946, but equipment is in poor condition. As elsewhere in Europe, there is still a great lack of serviceable equipment of even the most ordinary kind. Refinery capacity, largely destroyed, is restored sufficiently to meet current needs.

In the eastern or Russian zone of occupation, socialization of the oil industry has begun. This applies mainly to distribution, since there is no production, and to the synthetic oil industry. The latter has been reactivated in the Russian zone but is not operating in the western zones.

AUSTRIA

Cumulative oil production in Austria totals about 44,000,000 barrels. The 1946 production rate was about 11,875 barrels daily. All of Austria's production has come from 4 fields of the Vienna basin. Production has grown in recent years from about 1,000 barrels daily in 1938 to 5,000 barrels in 1942 and a peak estimated at about 23,000 barrels daily in 1944. This high rate was brought about by forced exploitation and with little regard for good production practice. About two-thirds of 1946 production was from the Prinzendorf field.

During the war (1942) the Aderklaa gas fields were opened. It is reported that the Soviet Crude Oil Administration in Austria brought in a 1,350,000-cubic-foot gas well near Vienna in October, 1946. Several exploratory wells have been drilled recently in the Austrian Province of Burgenwald. Exploration in other basin areas of Austria have so far been unsuccessful.

The position of the foreign companies in Austria is complicated by the definition of "German Assets" under the Potsdam agreement. Russia takes the position that foreign properties that were confiscated by the Germans after the Anschluss, fall under this definition and hence may be taken over by them. This position is contested by the United States and other allied governments.

GERMAN OIL FIELDS
OIL FIELD
GAS FIELD
REICH SUBSIDIZED BORE
0 25 50 KM.
Heligoland
Kiel
Heide
SCHLESWIG-HOLSTEIN
Lübeck
Hamburg
Reitbrook
Wesermünde
Etzel
OLDENBURG
Gotdorf
Heckelfeld
NORTH HANNOVER
Elbe
Bremen
ALLER
SOUTH BORDER OF POMPECKJ UPLIFT
NIEDERLANDE
COEVORDEN
Lingen
Georgsdorf
WEST HANNOVER
Bentheim
Hademstorf
Steimbke
Wietze
Adolfsglück
Fuhrberg
Nienhagen
HANIGSEN
Eicklingen
Ehra
Gifhorn
CENTRAL HANNOVER
Eddesse
Oberg
Molme
Mohenassel
Brarstedt
Failstein
Ems
Munster
Weser
FORST-WEIHER
WEINGARTEN
PECHELBRONN
KARLSRUHE
RHINE RIVER
Inset showing
Rhine valley fields
THÜRINGEN
Kassel
Volkenrode
Forstberg

FIG. 9

HUNGARY

Production in Hungary has grown in the past 10 years from nothing to a high of about 27,000 barrels daily in 1943 and 1944, since when it has dropped to 14,000 barrels daily in 1946 from about 165 wells. Cumulative production totals 34,600,000 barrels.

The first large discovery of oil was made in Hungary in 1937 when the MAORT (New Jersey Standard) Company brought in the Budafapuszta field in southwestern Hungary. Lovaszi about 15 miles west of Budafapuszta on the Yugoslav frontier, was next discovered by MAORT in 1940, Budafapuszta and Lovaszi are Pliocene fields. Testing is going on at Ujfalu, a short distance southwest of Budafapuszta, on the frontier.

During the war about 35 exploratory wells were drilled in Hungary, two-thirds of which were drilled in southwest Hungary. The small Hahot field was discovered 12 miles north of Budafapuszta during the war; the production is reported to be coming from a buried dolomite ridge. Eastward of the oil-producing area, southeast in Hungary, two small gas and condensate fields are reported to have been found in recent months.

The Hungarian fields have suffered greatly from excessive production and other uneconomic practices during the war and subsequently.

Russian troops, which had occupied the oil fields since their recapture, are now withdrawn. However, the Russians still exercise military supervision of the operations to insure priority on oil delivery to the Russian refinery in Hungary. The management of the American Company owning the fields now has access to the fields but still only on military permits.

There has been difficulty in getting a proper price from the Government and in obtaining payment from the refineries because of their difficulty in collecting from the Government.

CZECHOSLOVAKIA

Cumulative oil production in this country approximates 3,900,000 barrels. Current production is about 525 barrels daily and comes from the Gbely and Hodonin fields in the northeast extension of the Vienna basin of Austria. A discovery has been reported at Gross-Bilowitz on the frontier of Moravia and lower Austria in the same basin.

Under a 2-year plan, Czechoslovakia is said to be undertaking appreciable exploration. Two tests are reported drilling in western Slovakia, and exploration is going on in south Moravia. It is also reported that preparations are being made to continue the search for gas in Moravia near the Polish border where gas had previously been developed.

POLAND

Annexation of eastern Poland by Russia deprived Poland of at least three-fourths of its pre-war potential, including the main Boryslaw area. Boryslaw it-

self was approximately a 200 million-barrel field. Production in pre-war Poland was about 9,000 barrels daily. Production from hand-dug wells and trenches began in Galicia along the Carpathian foothills as early as 1854, and the first well was completed in 1861. Only one minor field has been found in Poland since 1913. Peak production of 41,000 barrels daily was attained in 1909.

The oil industry is now run by the Central Governing Body of the Industry of Liquid Fuels. The immediate goal is to build production to meet domestic demand by 1948. Sabotage and destruction during the war, overproduction by the Germans, and lack of equipment are making this a difficult task. Production is now said to be running at about 2,400 barrels daily in present-day Poland. Cumulative oil production totals about 270 million barrels.

It is reported that plans called for the drilling of 93 wells during 1946, about 17% of which were to be exploration. It is believed that this goal was approximately attained. Reported plans for 1947 call for about a 65% increase in drilling over that for 1946. Exploratory drilling has been concentrated on old geological and geophysical prospects. It is said that most of the geological and geophysical records existing when the Germans overran Poland were taken to Germany, and that many of the old technical personnel are now dead.

Most of the oil industry properties in the area that was annexed from Germany have been confiscated. The main fields of pre-war Poland annexed by Russia are being energetically re-established in an effort to assist in supplying Russia's need for oil.

It is reported that in the area of Poland annexed from Germany, preparations are being made to prospect around Bydgoszcz (Bromberg) which lies on the plains half way between Poznan and the Baltic. There are reports of a gas strike having been made in Silesia, which is also in western Poland. To further aid in supplying her liquid fuel needs, the creation of a synthetic oil industry has been started, using the large reserves of coal in the country.

ROUMANIA

Roumania, Austria, Hungary, and Germany account for nearly all of Europe's current production west of Russia of around 125,000 barrels daily. Roumania, by far the largest European oil producer west of Russia, has a cumulative production of around 1,145 million barrels. The first boring for oil in Roumania was apparently made about 1880, though, as in Galicia, hand digging of wells dates back prior to 1860. As in Poland, all of the discoveries were made along the Carpathian foothills belt.

Nearly all of Roumania's oil has been produced from an area around Ploesti about 40 miles long by 15 miles wide. Production had grown to about 20,000 barrels daily in 1920. Though only three major discoveries were made in the 1920–1936 period production increased substantially to about 178,000 barrels per day in 1936 due to the intensive drilling up of the prolific foothills structures. Daily output decreased thereafter to around 127,000 barrels in 1939 and to about

70,000 barrels in 1944 when the refineries and transportation facilities were under aerial bombardment. Production increased to 95,000 barrels per day in 1945 after the capture of the fields by the Russians, only to continue the decline that had set in before the war. Output in 1946 was at the rate of 86,000 barrels daily, and the Roumanian Petroleum Association forecasts a rate of 76,000 barrels per day for 1947.

The bulk of the production comes from the Pliocene on faulted and salt diapir folds. Per-acre yields are very high. A few small fields occur in eastern Roumania. Three of these produce from the Oligocene and the remainder from the Miocene.

During the early war years, 1940–1943, approximately 50 wildcat wells were drilled in a German inspired attempt to find new production. Most of the wells were drilled in or near the Ploesti area, where three minor discoveries or field extensions resulted.

Several reasons account for the scarcity of new field discoveries for a long period. Principal of these is perhaps the fact that rewards for successful exploration under the petroleum laws have been too small and too insecure. The result has been an intensive exploration of old productive properties, made possible by the high yields. There has been very little investigation of the extensive, geologically blind basin areas out in front of the foothills.

In the Transylvania area of Roumania the Pliocene is not favorably developed and only dry gas has been found. Three new gas fields were discovered during the war, making 9 in all. The gas is reservoired in upper Miocene (Sarmatian) sands. Production in the 1943–1945 period averaged 18,700 million cubic feet yearly. It was recently reported that an additional gas field had been discovered in Transylvania.

In 1942 a new Petroleum Law was passed. The law was designed to correct the major fault of the 1924 law and its 1929 and 1937 revisions. It is generally agreed that the latter laws had restricted wildcat drilling. They had provided insufficient incentive to carry on exploration work except in the areas of better prospects in the immediate vicinity of the Ploesti producing fields. In some cases the successful explorer had to return to the State as much as 85% of the area proved productive through his exploration work. The 1942 law is more liberal in this respect, but there is agreement that it is also most unsatisfactory.

Roumania entered the war with a refinery capacity nearly double that of production. Aerial bombing eliminated much of the refinery capacity, but since the war this capacity has been built back to around 140,000 barrels per day.

Since the close of the war a joint Soviet-Roumanian Oil Company called Sovrom Petrol has been formed. This company is made up of certain Roumanian companies and of former German-owned companies or companies taken over by the Germans. These latter are taken into Sovrom as Soviet contributions. The agreement between the Roumanian and Soviet governments gives the Sovrom Company preferential rights over the companies with other foreign capital.

Under the armistice agreement and peace treaty Roumania is obligated to pay

reparations amounting to 300 million dollars over a period of 8 years (later increased to 10 years) in commodities, the most important of which is oil. The bulk of Roumania's oil is currently sold by the companies to the Roumanian Government at low fixed prices. The oil is then turned over to Russia in reparations payment. Prior to the war most of Roumania's oil exports moved westward to help supply the markets of Europe. As there is now no exportable surplus there is in consequence, no exchange with which to buy much needed equipment.

ITALY

Production of oil in small quantities in Italy dates back to 1860. Prior to 1890 production amounted to only a few barrels a day. From 1890 to 1930 production averaged between 100 and 200 barrels daily. Peak Italian production of 570 barrels daily average was reached in 1932. The 1946 output averaged about 250 barrels daily from about 15 fields. Cumulative production totals about 3.2 million barrels. Most of the production has come from the Parma-Piacenza area along and near the Apennine foothills belt of northern Italy.

There is no reliable information on exploration activity during the war. To 1943, exploitation and exploration drilling remained relatively high. Two minor oil fields, Vizzola and San Giorgio, were discovered in 1941 and 1942, respectively.

The principal development during the war was the opening of shallow gas-producing areas, largely in the eastern Po plains. This activity was spurred by the fact that gas became a substitute for gasoline during the war. Many small operators actively drilled for shallow methane gas in the Quaternary of the eastern Po plains-Po delta region. In the southern plains area, adjacent to the foothills, the old Podenzano gas field was exploited nearly to exhaustion, and gas was developed at San Giorgio along the same belt on the east. These are Plio-Miocene fields.

A wet-gas discovery near Lodi, southeast of Milan, in 1943 on a seismograph structure was at first thought promising, but 3 additional wells drilled here were unsuccessful. Two Quaternary gas fields, Bando and Malalbergo, were discovered in 1943 on gravimeter structures in the southeastern plains south of Ferrara. Gas production in Italy in 1946 totalled about 2.5 billion cubic feet.

Exploration in central and southern Italy developed nothing of importance in recent years. Likewise, on the Island of Sicily, wildcatting carried on in the early years of the war resulted negatively. It was recently reported that an American company has been granted a concession to explore about 32,000 acres in the Licato, Aragona, Cattolica, Jappolo, Gientascio, and other areas of Sicily.

ALBANIA

Albania has produced nearly 10 million barrels of oil from the Devoli area of the Dinarides foothills back of Valona on the eastern Adriatic coast. The oil is developed in several adjacent Miocene pools in the area. We have no authentic information on the present status of the Devoli fields or of production in 1946. The field was discovered in 1928 and extensive development began in the middle

1930's. The 1945 production is reported to have run at about 2,000 barrels daily.

There was a recent report to the effect that Yugoslavia has proposed to Albania that Albania pool her oil reserves with Yugoslav technique for joint exploitation.

SPAIN

No commercial oil or gas fields have as yet been developed in Spain. Three companies were actively exploring for oil in 1946.

CAMPSA (Compania Arrendataria del Monopolio de Petroleo Sociedad Anonima), the Government-monopoly company, is drilling a well as Zamanzas in Burgos Province. It is reported that 3 drilling sites have been selected, one at Ubierna in Burgos Province, one at Cuenca in Soria Province and one at Tremp in Lerida Province, northwest of Barcelona. This company carried on core drilling, during the year.

CIEPSA, a combination of Cia. Espanola de Petroleo, S.A., and the Socony-Vacuum Oil Company, are preparing to drill a test at Oliana, Lerida Province, in the Ebro basin.

ADARO, a subsidiary of the Instituto Nacional de Industrias, is preparing to drill on a Triassic anticline at Chiclana near Cadiz in southwestern Spain.

The Geologic Institute is operating a Sullivan rig of 5,000 feet capacity on a test near Villaciervos, a few kilometers west of Soria in northern Spain.

While all of the several basins in Spain have been investigated from time to time, those of northern Spain have in the past, as to-day, received the most attention.

TURKEY

Oil production in Turkey has been negligible. Drilling near the eastern section of the Syrian frontier encountered minor production. Recent reports indicate that Turkey is preparing for more energetic exploration and is enlisting American help for training men in various phases of exploration work.

RUSSIA

Cumulative production in Russian territory approximates 5,600 million barrels. It is impossible to get accurate figures of daily production over recent years. Best information available indicates that 1946 production has been approximately 450,000 barrels daily, a rate about 41% of that of Venezuela. This is comparable with about 620,000 barrels daily in 1940 and about 400,000 barrels in 1945.

It is reported that 3,000 wells were destroyed in the productive areas of the Caucasus occupied by the invading armies. It appears evident that the industry suffered also from loss of refining capacity and from the slowing of exploration caused by the war. Besides, there is a very great need for new equipment. This requires foreign exchange for the equipment or for materials to make it. It has been officially stated that Russia plans to spend 200 million dollars a year over the

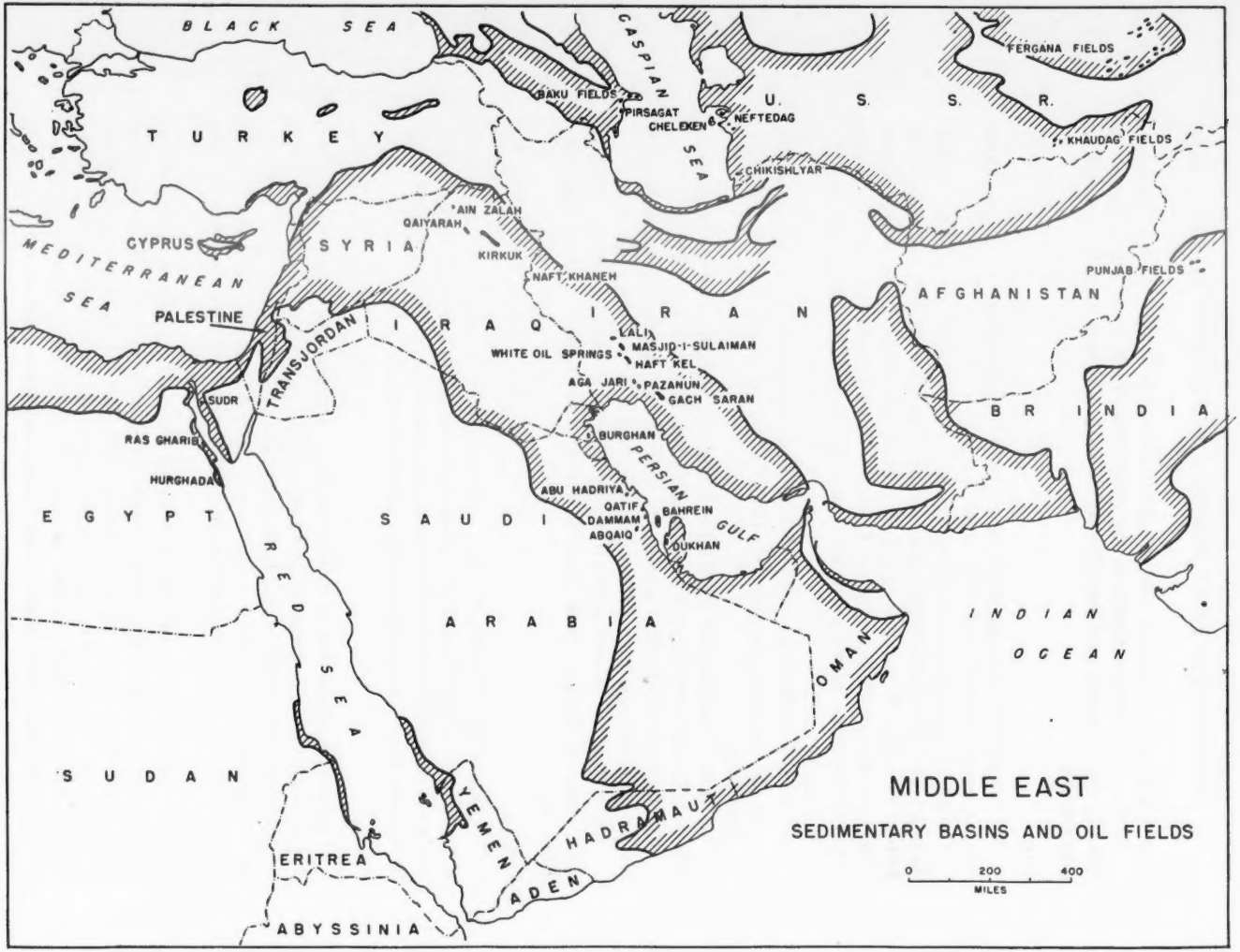

BLACK SEA
CASPIAN SEA
FERGANA FIELDS
BAKU FIELDS
PIRSAGAT
CHELEKEN
NEFTEDAG
U. S. S. R.
TURKEY
KHAUDAG FIELDS
CHIKISHLYAR
AIN ZALAH
QAIYARAH
CYPRUS
SYRIA
KIRKUK
MEDITERRANEAN SEA
NAFT KHANEH
PUNJAB FIELDS
AFGHANISTAN
PALESTINE
TRANSJORDAN
IRAQ
IRAN
LALI
MASJID-I-SULAIMAN
WHITE OIL SPRINGS
HAFT KEL
AGA JARI
PAZANUN
GACH SARAN
SUDR
BRITISH INDIA
RAS GHARIB
BURGHAN
PERSIAN GULF
HURGHADA
ABU HADRIYA
QATIF
DAMMAM
BAHREIN
ABQAIQ
DUKHAN
EGYPT
SAUDI ARABIA
RED SEA
INDIAN OCEAN
OMAN
SUDAN
YEMEN
HADRAMAUT
ERITREA
ADEN
ABYSSINIA
MIDDLE EAST
SEDIMENTARY BASINS AND OIL FIELDS
0 200 400
MILES

FIG. 10

next 5 years for industrial equipment of which about one-tenth is scheduled for the oil industry. In addition to the large amounts of oil being brought in from the Balkan countries now under Russian domination, figures for 1945 show that 4,787,500 barrels of oil were imported from the United States.

The Caucasus fields, particularly those of the eastern Caucasus Baku area, have long produced the great bulk of Russia's oil. Just prior to the war the Caucasus supplied about 86% of the country's oil, of which about 72% was from Baku. These proportions have since dropped to about 70 and 61%, respectively.

The balance has been made up by increases in other areas principally that of the so-called Second Baku region on the north which lies between the Volga River and the Urals. Output in this region increased from only 6% of all Russian production just prior to the war to about 15% at present. Reports indicate that, it is hoped that by 1950 all Russian fields outside the Caucasus region will provide 36% of Russia's production.

It is interesting to note a few figures that appear in reports of future plans. The production goal for 1950 under the current 5-Year Plan is given as 257 million barrels, and as 436 million barrels for 1960. The 257 million-barrel figure (700,000 barrels daily) is smaller than the goal set but not attained under the second 5-Year Plan prior to the war. The goal set for the Baku area for 1950 is only 123 million barrels; this is comparable with an actual production of about 175 million barrels in 1938.

As already reported, the most successful developments in recent years have been in the "Second Baku" region between the Volga and the Urals. Rather large discoveries have been made at Tuimazy, Kuibyshev and Saratov on the Volga, and at Ufa, Sterlitamak, and other localities nearer the Urals in this region. The Kuibyshev field is said to have quadrupled its pre-war production.

Considerable developments are reported in the Ukhta district of the Komi Republic where the center of the industry for North Russia, west of the Urals, is now located. Other areas of developments in East Russia include that of the Kama fields, 400 miles south of Ukhta, and several other areas still farther south in the Ural geosyncline. Production in the Uralian geosyncline is from the Paleozoic, whereas that of the Caucasus fields and the areas east of the Caspian is Tertiary in age. Significant is the fact that the recent discovery at Tuimazy on the Volga is from the Devonian.

In the Baku region a 12,800-foot test, said to be the deepest in Europe, is reported to have been drilled. Prospecting is now proceeding in what is known as the Small Caucasian Range in southern Azerbaidjan. A new oil field was recently reported at Buzovny in Baku; another is reported at Task-Kala in the Grozny area. Just east of the Caspian, on the trend of the Caucasus, where the Nebit-Dag fields are located, the Buzovna and Mashtaga fields were brought in during the war. Production in this area is said to have reached 14,000 barrels daily in 1945, and the area is destined to increase in importance.

While numerous indications of oil are known in Siberia, the development of

FIG. 10

many of its prospective areas will probably be long delayed due to the lack of transportation and the ice-bound character of its coast and rivers during most of the year.

Pre-war production on Sakhalin Island approximated 13,000 barrels daily, about equally divided between the north and south halves of the island. It is reported that there has been some increase during the war and subsequently. Exploration is said to be going on in these Tertiary basins both in North Sakhalin and in the southern half, which was taken over from Japan. Exploration is also reported to be proceeding on Kamchatka Peninsula.

There have been various claims made regarding the extent of Russian reserves. One report in 1937 gave a figure of 46 billion barrels, or much greater than the proved reserves of the rest of the world at that time. Obviously such claims are not made on the same basis that proved reserves are figured in the rest of the world. However, the geology of Russia indicates large potentialities. Her sedimentary basin area is at least two and possibly as much as two and a half times that of the United States.

IRAN

Cumulative oil production in Iran totals about 1,590 million barrels. Production is about 410,000 barrels daily. The large Haft Kel field is furnishing the largest part of the current production.

The original D'Arcy 500,000 square-mile concession, covering all of Iran except the five northern provinces, was obtained in 1901 from the old monarchy. The present Anglo-Iranian Oil Company is owned 56% by the British Government. Anglo-Iranian began developments at Naft Khaneh on the Iraq border, or what was at that time the border of the old Turkish empire. Activities were later shifted to the more accessible area of southwest Iran on the Persian Gulf, where the Masjid-i-Suleiman discovery was made in 1908 and where production began in 1913. Haft Kel was discovered in 1925, followed by Gach Saran, Agha Jari, White Oil Springs, and the Pazanun gas field. No new discoveries were made during the period 1940–1946.

The original concession was revoked and replaced by a new contract limiting the area to 200,000 square miles to run for 60 years from December 31, 1933, with obligation to further reduce the area to not over 100,000 square miles within 10 years. Only a small part of this 100,000 square mile area of southwestern Iran has been explored by the drill. Exploratory activity in recent years has been limited to a moderate amount of geological and seismic work.

Under the present monarchy all petroleum concessions must be approved by the Majlis or Parliament. The concession negotiated by Russia covering the five north Iranian provinces has not yet received this approval. The question of ratification is due to come up early in 1947 after the seating of the newly elected parliament. The contract calls for 51% Russian and 49% Iranian participation in the company, with Russian operation. The contract terms are very like those

set up in the countries of Europe under the control of Russia and are quite different to any type of concession contract now in effect in the Middle East.

The Standard Oil Company (New Jersey) and Socony-Vacuum Oil Company have recently contracted with Anglo-Iranian for the purchase of crude oil from Iran and Kuwait.

COUNTRIES UNDER CONCESSION TO IRAQ PETROLEUM COMPANY GROUP

The countries of this group are: Iraq, Syria, Lebanon, Palestine, Cyprus, Qatar, and the Trucial Coast.

Cumulative production from this group, virtually all of which came from the Kirkuk field in Iraq, amounts to about 320 million barrels. In addition, about 24 million barrels of oil has been produced from the Naft Khaneh (Iraq)—Naft-I-Shah (Iran) field and surface structure which lies astride the Iraq-Iran boundary. The field was discovered in the middle 1920's. Kirkuk was discovered in 1927. It produces from Tertiary limestone, approximately equivalent to the late Eocene to early Miocene Asmari limestone of Iran. Production at Kirkuk started in 1934 after the completion of the pipelines to Haifa and Tripoli on the Mediterranean. Production has been maintained rather continuously at the 80,000–90,000 barrel capacity of the line, except for the period of the war when the Mediterranean was closed. Iraq daily production totaled about 96,000 barrels.

A new 16-inch pipeline paralleling each of the two 10-inch and 12-inch existing lines is under construction. On completion the pipeline capacity will be raised to 250,000–300,000 barrels per day. The increased pipeline capacity calls for replacement drilling of wells destroyed in the "denying-the-enemy" program.

Petroleum rights to the country of Iraq are held under three main concessions. The area east of the Tigris River is covered by the original Iraq Petroleum concession. Rights to the northern part of Iraq west of the Tigris are now subject to the Mosul Petroleum Company. And the Basrah Petroleum Company concession covers the southern area of western Iraq. Petroleum rights in the other countries previously listed are held under Petroleum Concessions, Ltd., and each is operated by a separate Petroleum Development Company. Most of these concessions are for a period of 75 years.

The Ain Zalah field of Iraq, 150 miles northwest of Kirkuk, was discovered in Upper Cretaceous limestone in 1939 by drilling on a well defined surface structure. The field, since extended by exploratory drilling, is now shut in. The Qaiyarah field on the west bank of the Tigris, 65 miles northwest of Kirkuk was discovered in 1927. It is one of a group of structures. The Germans had discovered a minor amount of shallow oil here in 1918. Qaiyarah oil is heavy and sulphurous. Other wildcat wells in Iraq and Syria were dry holes or non-commercial wells. The Dukhan field on Qatar Peninsula in the Persian Gulf was discovered in Jurassic limestone in 1940 and extended by exploratory drilling. The wells were destroyed by the operators during the North African campaign, and drilling was resumed in 1945.

Exploratory work was suspended in all areas of I.P.C. and P.C.L. operations from 1942 through 1945. In 1941, 3 exploratory wells were completed in Iraq and 2 in Syria. One exploratory well was completed in Qatar in 1941 and another in 1942. Plans for 1947 contemplate the drilling of 3 wells in Iraq, 2 in Syria, 2 in Palestine, 1 in Lebanon, and 3 in Qatar.

In 1941 one or two geological parties were working in each of the 7 countries. In addition, a geophysical crew was operating in Iraq and another in Palestine. In 1946, 11 geological parties and 8 geophysical crews were operating in 6 of the countries. It is contemplated that 13 geological and 7 geophysical parties will be active in 1947. It is anticipated that new oil discoveries will be made in this oil rich province, where untested prospects embrace geologic structures of large magnitude.

SAUDI ARABIA AND BAHREIN

Cumulative oil production in Saudi Arabia is about 112 million barrels, and nearly 80 million barrels for Bahrein. Respectively, current production is 200,000 barrels, and 20,000 barrels daily for the two countries. Concessions in both Bahrein and Saudi Arabia are owned by the Standard of California and Texas Oil Company. The concession in Saudi Arabia covers 435,000 square miles, an area about the size of that of Texas, Oklahoma, Arkansas, and Louisiana combined.

Oil was discovered on the island of Bahrein in 1932. The main production comes from middle Cretaceous sand and limestone. Drilling on Bahrein was suspended during the war. One rig is now reported to be running. It is further reported that the drilling of exploratory wells for structure around the island is planned. The main productive beds in the four fields discovered to date in Saudi Arabia are in Jurassic limestone. The deep or main producing formation at Dammam, located directly across the straits from Bahrein, was discovered in 1938. The large Abqaiq field about 40 miles southwest of Dammam, was discovered in 1941. At least 1,450 feet of oil leg has been proved in Abqaiq by well No. 10. Four wells were said to be drilling on Abqaiq and one on Dammam around the close of 1946. Abu Hadriya, located about 80 miles north of Dammam, was discovered in 1940. So far only the discovery well has been drilled on this structure. Qatif, discovered in 1945 just north of Dammam is also still a discovery well field. Of the current production from Saudi Arabia about 100,000 barrels daily is derived from 9 wells at Abqaiq, an approximately equal amount from 45 wells at Dammam and around 3,500 barrels from the one well drilled on Qatif.

In reviewing the Middle East fields, it is of interest to note that 750,000–760,000 barrels of oil are being produced daily. This production is nearly 70% above that of Russia. Probably no other oil area of the world of similar size has potential reserves of comparable magnitude. No other area of the world has average daily yields per well equalling those of the fields around the Persian Gulf, which run from several hundred to more than 10,000 barrels per well per day.

Instead of reduced demands for oil with the close of the war outlet has actually

increased. Much of the oil is moving to supply markets that would normally be supplied by Far Eastern fields. As the Far Eastern fields are being rehabilitated plans are going forward to build pipe lines to the Mediterranean from Saudi Arabia, Kuwait and Iran. These will cut the 3,100- to 3,300-mile tanker haul to the Mediterranean to about one-third that distance.

KUWAIT

The Burghan oil field in Kuwait was discovered in 1938 on a reflection-seismograph structure. The concession, which covers the entire 6,000 square mile sheikdom, is owned by the Kuwait Petroleum Company, Ltd., the ownership of which is equally divided between the Gulf Exploration Company and the Anglo-Iranian Oil Company. The wells were plugged and operations suspended during the war. Deliveries from the field, which began in May, 1946, are currently running at 40,000 barrels daily. It is reported that 8 flowing wells have been drilled. Cumulative production at the close of the year was close to 7 million barrels.

The reservoir of the Burghan field is a thick middle Cretaceous sand. The oil is reported to be of 32° A.P.I. gravity. The Burghan structure is said to be very large. Various estimates have placed the reserves at 4 to 5 billion barrels, with potential possibilities of double these figures.

It has been recently reported that the company plans to start 7 more rotary rigs drilling on the field in 1947.

EGYPT

Cumulative production in Egypt, all of which has come from the Gulf of Suez area, totals about 98 million barrels. Current production is more than 25,000 barrels daily from about 128 wells. Nearly all of this is coming from the Ras Gharib field discovered by Anglo-Egyptian Oilfields (Shell) in 1939. About 1,000 barrels daily is coming from the old Hurghada field discovered by the same company in 1913. Both of these fields are on the west side of the Gulf of Suez. Ras Gemsa, a very minor shallow field, also on the west side of the Gulf was discovered in 1911. On the east side of the Gulf the old abandoned Abu Durba field, opened in 1918, has yielded a little oil. On the same side of the Gulf, discovery of oil at Sudr in a joint operation of Anglo-Egyptian and Socony-Vacuum was made in 1946. One well is now reported to be drilling at Ras Gharib and one at Sudr.

Altogether 109 wildcat wells have been completed in Egypt to date: 72 of these were drilled on the west coast of the Gulf of Suez, 18 on the east coast of that Gulf, 12 along the Red Sea, 3 in the interior of Sinai, and 4 in the Western Desert (west of the Nile). Exploration activity was greatly curtailed during the war years, but was resumed in 1945 and 1946, in which years 14 wildcats were completed. In the latter part of 1946, the Standard Oil Company of Egypt, Anglo-Egyptian Oilfields, and Socony-Vacuum Oil Company were operating 3, 2, and 2 wildcat rigs, respectively.

A limited amount of seismic and gravity-meter work was carried on in Egypt in 1946. Of particular interest is the fact that the three main operators are co-

operating in running an experimental seismograph to improve technique and to determine which areas may be worked, for seismograph results in Egypt have been generally disappointing.

Large areas of Egypt are as yet unexplored. In the near coastal areas of the Western Desert where the North African campaign was fought thousands of land mines laid by the opposing armies still remain buried. Under the dry conditions of the desert these mines may remain a menace to exploration for many years unless removed.

INDIA

Cumulative oil production in British India totals approximately 49 million barrels. Current production is 6,500 barrels daily. The old Digboi Miocene field of northeast India in upper Assam, near which the Stilwell road starts out of the Brahmaputra Valley for China, produces about 5,400 barrels, and the Dhulian and Khaur fields of the Punjab, northwest India are reported to produce about 600 and 200 barrels daily, respectively.

In the southern or Suma Valley of Assam the old Badarpur field was abandoned in 1933, when it had a cumulative production of only 1,671,000 barrels. Exploration for many years of the Masimpur structure east of Badarpur and of the Patharia structure on the southwest resulted in only small amounts of oil from each. Large sums were spent in testing these structures.

The Punjab basin is between the Siwalik front of the Himalayas on the north and the Salt Range on the south. The oil of the Punjab fields occurs near the unconformable overlap of Miocene sediments on Eocene limestone, partly above but mainly below the unconformity. The Dhulian and Khaur fields, which are in the deeper north part of the basin, yield light oil, and heavy, viscous black oil is found in the Joya Mair field on the southern shelf. In June, 1946, a discovery was made in Balkassar No. 1, 12 miles west of Joya Mair, reported at 350 barrels daily. This oil is also asphaltic but it is of better quality than that at Joya Mair. A second well is being drilled. The fields of the Punjab are operated by the Attock Oil Company. Production at Dhulian, the main field, has been falling off rapidly since 1940 with water encroachment.

The Khaur field was discovered in 1913, Dhulian in 1935, Joya Mair in 1944, and Balkassar in 1946. A test at Meyal was abandoned at 10,501 feet. Another test is reported to be drilling at Bakra. A recent report states that a deeper oil showing has been discovered at Joya Mair. It was also recently announced that the Burma Oil Company is drilling a test near Joya Mair.

Soon after the outbreak of the war most of the exploratory work of all types was suspended in India except for some wildcat drilling in the Punjab. Suspension of exploration was accompanied by a moratorium on concessionary obligations. In 1946 geological work was again started both in northwest and eastern India. Two seismic crews were scheduled to start surveys in northwest India and some gravity work was recently going on near the Digboi area of Assam.

BURMA

Production from British India and Burma had generally been reported as one total in the United States prior to 1935. With the assistance of data from British sources it is indicated that cumulative production in Burma alone totals approximately 282 million barrels. Prior to the Japanese advance into Burma in 1942, production was about 21,000 barrels daily from about 5,000 wells in 10 fields. The bulk of this oil was coming from Singu and Lanywa, and most of the remainder from Yenangyat and Minbu.

There is little authentic information on the present status of the Burma fields and their production. Much damage resulted from sabotage carried out by the British prior to evacuation, and also from aerial bombing and political unsettlement. It has been reported that the Government has refused to pay the companies for the damage resulting from the war. It is also stated that between the British military occupation forces and the Burmans approximately 2,000 barrels per day has been produced from the fields over the past year. This rate would be only about one-tenth that of pre-war. Besides the extensive damage to the producing properties, it is reported that a complete new refinery will have to be built.

The Burma oil fields are in the basin of the Irrawady Valley. The oil reservoir is in Oligo-Miocene strata, which is approximately the age of the oil-producing sedimentary rocks of Assam on the north. Recent reports state than an American geophysical crew has arrived in Burma.

CHINA

Greater China, with an area 30% larger than that of the United States, has been relatively little explored. A number of sedimentary basins are known, as outlined approximately on the map. One of the principal deterrents to exploration and development is the fact that the areas of better prospects are located as far as 2,000 miles or more by road over a rough and arid country from the centers of population.

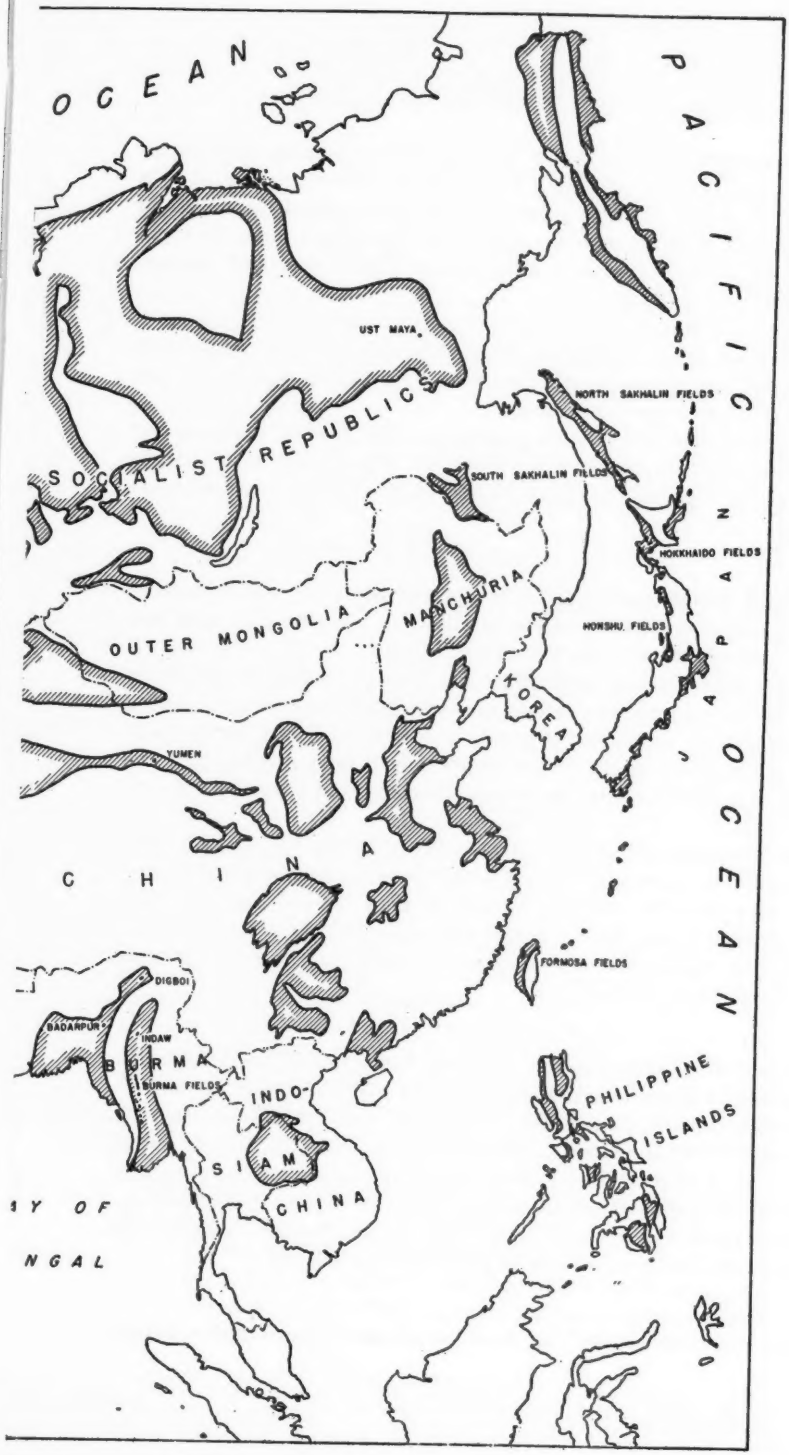
Cumulative production in China is only about 3 million barrels. Though the production of very minor quantities of oil dates back for several thousand years the only important oil field, that of Yumen (sometimes called Laochunmiao), was discovered in 1939 in northwest Kansu, 1,500 miles northwest of Chungking by road. About 30 wells have been drilled, and production has run as high as 3,000 barrels daily of 33° A.P.I. oil. Production in 1946 is variously reported at from 1,000 to 2,000 barrels a day. The oil is refined at the field and the products are trucked to markets. The oil reservoir is in Tertiary sands. Various estimates give reserves of 50–100 million barrels for the field.

In the Szechwan or Red Basin, in which Chungking is located, a little oil and gas has been found in many wells drilled for brine during the past more than 2,000 years, and more recently in exploration for oil and gas. The basin contains many folds.

Reports indicate that the Russians developed oil in numerous wells which

ARCTIC
EUROPE
UNION OF SOVIET
BLACK SEA
TURKEY
MEDITERRANEAN SEA
SYRIA
IRAQ
CASPIAN SEA
AIN ZALAH
QAIYARAH
KIRKUK
CHELEKEN
NEFTEDAG
CHIKISHLYAR
KAFT KHANEH
FERGANA FIELDS
WU SU
KAUDAG FIELDS
IRANIAN FIELDS
IRAN
BURGHAN
SAUDI ARABIA
ARABIAN FIELDS
BAHREIN
DUKHAN
RED SEA
AFGHANISTAN
PUNJAB FIELDS
INDIA
ARABIAN SEA
ASIA
SEDIMENTARY BASINS
AND
OIL FIELDS
0
500
1000
1500
MILES

FIG. 11


OCEAN
PACIFIC
UST MAYA
NORTH SAKHALIN FIELDS
SOCIALIST REPUBLIC
SOUTH SAKHALIN FIELDS
HOKKHAIDO FIELDS
OUTER MONGOLIA
MANCHURIA
HONSHU FIELDS
KOREA
YUMEN
CHINA
FORMOSA FIELDS
DIGBOI
BADARPUR
INDAW
BURMA
BURMA FIELDS
INDO-
PHILIPPINE
ISLANDS
SIAM
CHINA
OF
NGAL

they drilled several years ago in northwest Sinkiang (Tsungari basin) in far northwest China. The data indicate that oil of high grade as well as gas was found in several localities. It is said that the Russians have since capped the wells and moved out. A number of oil seepages are reported in this remote basin. Seepages have also been long known in the Tarim basin west of Kansu, also a very remote, arid and very little inhabited region.

A very little oil has been developed in the Shensi basin and also in the north Manchuria and Jehol basins. There are large oil-shale reserves in Manchuria which the Japanese had exploited for as much as 3,000 barrels daily. There are also other large oil-shale deposits in China.

There are a number of oil-bearing structures on the island of Formosa, but only three of these might be termed commercial, the principal of which is Shukkada in northwestern Formosa. It is reported that production has been 100 to 200 barrels daily.

JAPAN

Cumulative oil production in Japan is approximately 93 million barrels. Daily output is now approximately 4,000 barrels. It is reported that some new production was developed in the Hachimori field in 1946.

Japan's Cretaceous-Tertiary basins have not been efficiently or completely explored. The producing areas are limited to northwest Honshu and the central part of Hokkaido. All oil production is largely or entirely of Upper Tertiary age. Alluviated or plains areas of the basins have scarcely been investigated, and there has been very little exploration of lower Tertiary and Cretaceous formations.

Most of the producing industry in Japan is owned by the Imperial Oil Company, whose ownership is equally divided between the Government and private capital. Ambitious plans for pushing exploration since the war have not been effectively implemented and drilling is still limited to the old producing areas.

It appears that elimination of synthetic oil production and limitation of refinery capacity in Japan is likely.

PHILIPPINES

There has been a moderate amount of drilling for oil in the Island's Tertiary basins. Indications of oil have been found in several wells. The main areas of activity have been in southern Luzon, Cebu, and Leyte. The Far East Oil Development Company of the Philippines has recently announced contracting for resuming drilling on one of the two structures on the Island of Cebu on which exploration was interrupted by the Japanese invasion. Prior to the war a discovery was claimed on the structure in the north part of the island. The other structure lies in central Cebu. Other tests are said to be planned in the Islands.

EAST INDIES

Cumulative production in the East Indies totals about 1,230 million barrels,

of which 90% or more was produced in the Netherlands East Indies and the balance in Borneo. Prior to the war the oil output of the Far East, which includes the East Indies, India, Burma, Japan, approximated 220–225 thousand barrels daily. Current production is about 50,000 barrels daily. Practically all of this drop in production can be attributed to sabotage of the properties in the East Indies and in Burma carried out under military orders just prior to the Japanese invasion and by the Japanese prior to reconquest by the Allied powers, and also to delay in rehabilitation on account of the political unrest, the need for new equipment, the problem of exchange and the tremendous task of re-establishment of the wrecked properties.

TABLE IV

OIL FIELDS DISCOVERED IN EAST INDIES, 1936–1946

Field	*Year Discovered*	*Discovered by*	*Discovery Credited to*
CENTRAL SUMATRA			
Doeri	1941	NPPM (Cal-Tex)	Surface geology; seismograph
Minas		By Japs on NPPM (Cal-Tex) property	Seismograph
Lirik	1938–39	NKPM (Std.-Vac.)	Surface geology
SOUTH SUMATRA			
Moesi (Gas field)	1938	NKPM (Std.-Vac.)	Seismograph
Rajah	1940–41	NKPM (Std.-Vac.)	Gravity meter
SOUTH BORNEO			
Tandjoeng (Moeroeng Poedak)	1938	BPM (Shell)	Surface geology
NORTHWEST NEW GUINEA			
Klamono	1936	*NNGPM	Surface geology
Mogoi	1941	*NNGPM	Surface geology
Wasian	1939	*NNGPM	Surface geology

*40% BPM (Shell).
40% NKPM (Std.-Vac.).
20% NPPM (Cal-Tex).

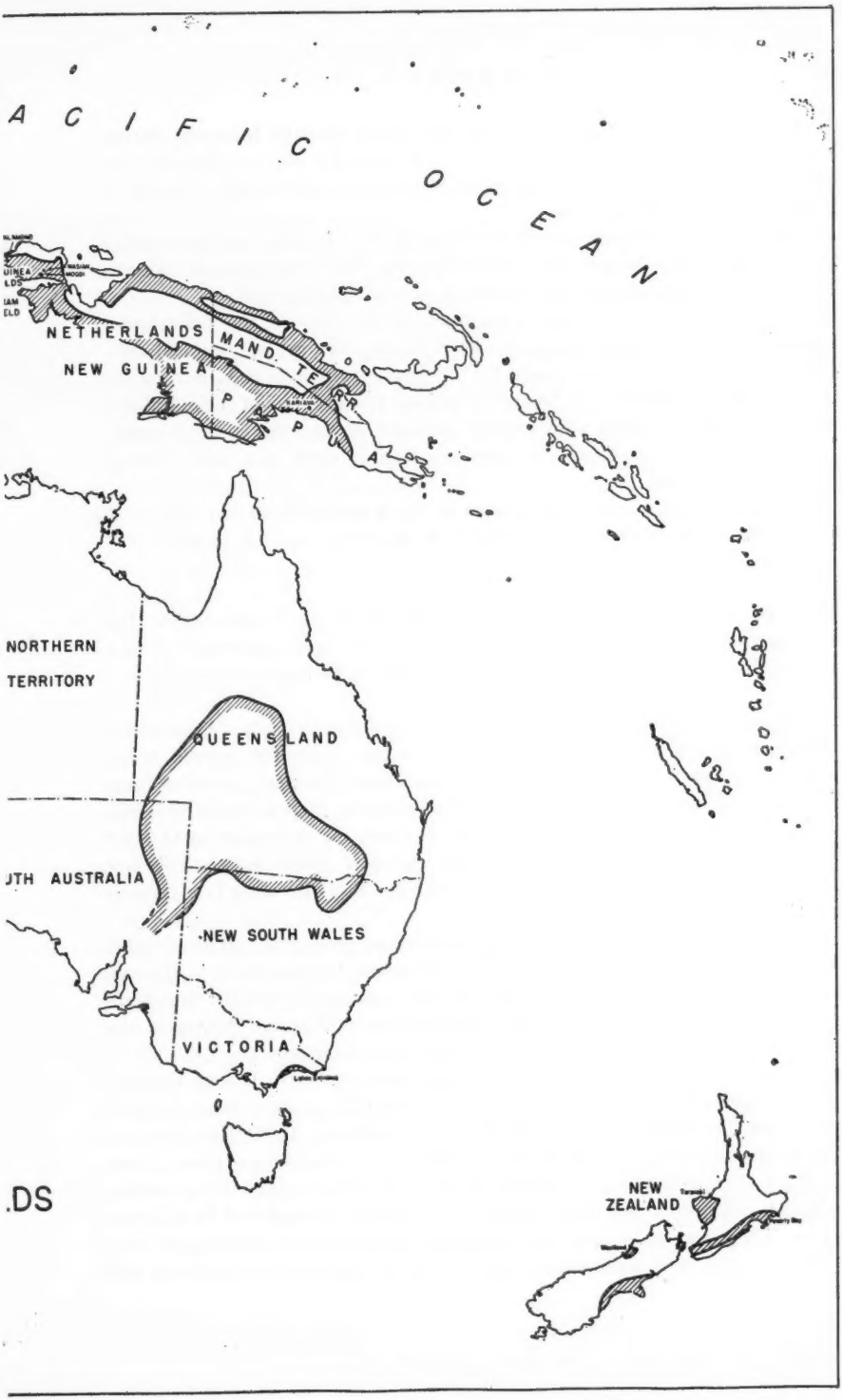
Prior to the Japanese invasion production in the East Indies was more than 180,000 barrels per day from about 3,400 wells. Of this total about 112,000 barrels daily was supplied by Sumatra, 50,000 from Borneo, 17,000 from Java, and about 2,000 barrels from Ceram. Currently, production in the East Indies is 35,000 barrels daily. While an increase in output will probably occur on settlement of the political and lesser physical difficulties, several years of rehabilitation may be required to return to complete normalcy. At present there is a considerable lack of balance between production, storage, transportation, and refining facilities.

In all productive areas the succession of events is essentially the same: destruction of storage, refineries, pipe lines, and wells prior to the enemy invasion; repair of some of the properties and restoration of production to the extent possible by the Japanese, concentrating on several areas where the possibilities of restoration and the type of oil needed offered most advantages; renewed sabotage by the Japanese prior to recapture; and now the slow process of recovery and re-

OCEANIA

SEDIMENTARY BASINS AND OIL FIEL

FIG. 12


A C I F I C
O C E A N
NETHERLANDS
NEW GUINEA
MAND. TE
P A P U A
NORTHERN
TERRITORY
QUEENSLAND
UTH AUSTRALIA
NEW SOUTH WALES
VICTORIA
NEW
ZEALAND

establishment of the properties. It has been estimated that the Japanese, during their occupation and under the pressure of the need for oil, had restored the production to approximately half of pre-war capacity. A considerable number of wells were drilled in certain fields.

On the Vogelkop, western end of Netherlands New Guinea, the three fields, Klamono, Wasian, and Mogoi, discovered before the war, were destroyed prior to Japanese entry. These fields are now in the process of rehabilitation.

In Papua, the southeastern part of the island of New Guinea, the Australasian Petroleum Company's well at Kariava, closed during the war, has resumed drilling. The Papua operations are owned by the Anglo-Iranian, Standard-Vacuum, and Oil Search, Ltd., the last an Australian company. A program of geological and geophysical work and aerial photography has been announced. A considerable amount of structural, stratigraphic, and geophysical work had been done in Papua prior to the war.

Table IV lists the oil fields discovered in the East Indies in the 1936–1946 period and the method or methods by which the discovery well was located.

AUSTRALIA

The area of Australia is but slightly less than that of the United States. The only oil production in Australia is that developed in small quantities from a coastal Tertiary overlap in the Lakes Entrance field in Victoria on the southeast coast.

Hundreds of wells have been drilled in the Great Artesian basin of Queensland for water and a few wells were drilled for oil or gas. Scattered, mostly minor showings of gas, some of it wet, and light oil have been obtained in some of these wells. The Great Artesian basin is several hundred square miles in area and is said to be the largest artesian basin in the world. It covers all of Southwest Queensland and adjoining parts of South Australia and New South Wales. This is a moderate-depth basin, filled largely with Cretaceous but with some late Jurassic and, locally, Triassic and late Paleozoic strata.

During most of the war years the Shell carried on geological and geophysical work on a 116,000 square mile concession in the Great Artesian basin of Queensland. The Zinc Corporation (Broken Hill Mines), assosiated with the Standard-Vacuum and Anglo-Iranian, have been granted an exploration license in the northwestern part of South Australia to develop gas for the mines.

At present Northwest Australia is receiving some attention. During the year the Freney Kimberley Oil Company and the Caltex Oil Company were the leading operators. The former is reported to be drilling a test on the Nerrima dome on its 550 square-mile block in the Kimberley District. Caltex had 134,000 square miles of acreage surrounding the Freney block in which it has been doing geological work. It is reported that this company has recently relinquished its rights to this area. The activities of these two companies were suspended during the war. The area is vast. The sedimentary rocks of main interest are Devonian and

Permo-Carboniferous in age. Eight wells have been drilled here since 1921, with only minor shows reported.

In the so-called Northwest basin, which extends along the west coast no drilling has been done for oil and gas, though wells have been drilled for water in the basin. The sediments are Carboniferous to Tertiary in age. No oil indications are known in this basin. It is reported that Cal-Tex have recently also relinquished a concession area which they held in this basin, on which they had done some geological work.

The Commonwealth Government has recently reported that it plans to spend about 12 million dollars in the search for oil in Australia, mainly in the Kimberley region. H. G. Raggatt, director of the Commonwealth Bureau of Mineral Resources, Geology and Geophysics, is in charge of the expanded program. Besides a 3- to 5-year geological and geophysical survey in the Kimberley region, beginning in 1947, it has been announced that geophysical surveys will be made of the prospective Broken Hill gas area at the southwestern end of the Great Artesian basin.

About 40 wells have been drilled in South Australia, most of them along the southeast coast. At best only minor showings of oil or gas are reported. The sedimentary rocks, which are partly Jurassic and largely Middle and Upper Tertiary in age are not very favorable in facies.

NEW ZEALAND

The search for oil in New Zealand has been localized largely in three principal districts, namely, Taranaki and Poverty Bay, on the east and west sides of the North Island, respectively, and the Westland district of the South Island. In each instance attention was attracted by oil seepages. Drilling efforts in Taranaki were centered largely on an igneous plug at New Plymouth where, in the 20 years preceding 1938, more than 40 wells were drilled, a few of which obtained small yields of oil. In all, 100,000 barrels of oil have been produced. Of the 16 wells drilled in the Poverty Bay area prior to 1938, none found encouraging indications. Earlier activities in the South Island were localized around the Kotuku oil seepages in the Westland area near Greymouth.

In 1938 a period of renewed activity was initiated. Geological and geophysical surveys and drilling were started by the New Zealand Petroleum Company, Ltd., a group composed of the Standard-Vacuum, Cal-Tex, and local New Zealand and Australian interests. This company drilled 8 tests with a total footage of approximately 52,000 feet, none of which met with encouraging results. Two of these wells were drilled in the Poverty Bay area, 5 in Taranaki, and 1 in the South Island. In addition, during the early years of the war, the Superior Oil Company and the Shell Company undertook geological and geophysical work, followed by drilling. The Superior put down 2 tests in the Manawatu-Rangitiki District of the North Island, and 2 in the Westland District of the South Island. The Shell also drilled a test in the Westland area. Results in each case were discouraging.

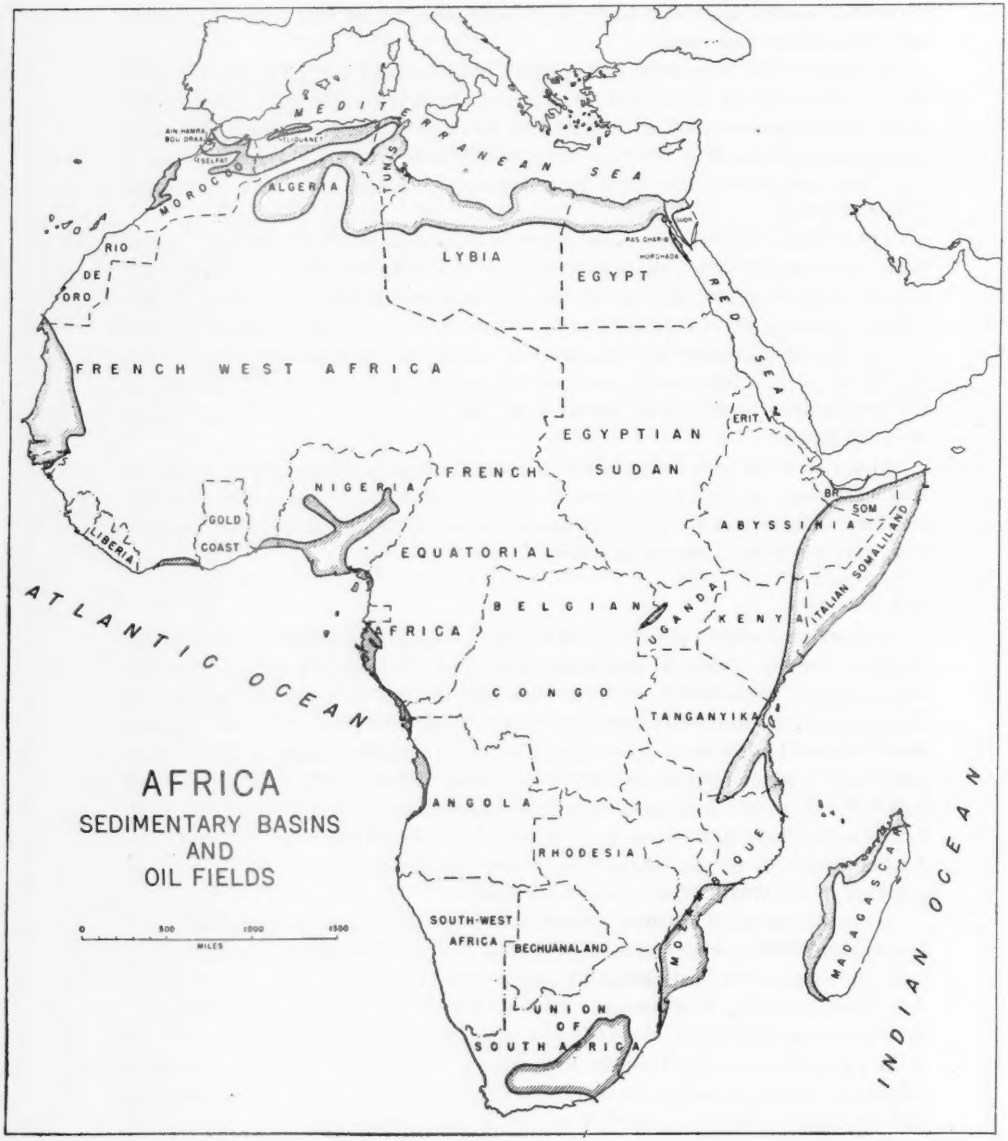

AFRICA
SEDIMENTARY BASINS
AND
OIL FIELDS
0 500 1000 1500
MILES
MEDITERRANEAN SEA
ATLANTIC OCEAN
INDIAN OCEAN
RED SEA
ALGERIA
LIBYA
EGYPT
FRENCH WEST AFRICA
EGYPTIAN SUDAN
FRENCH EQUATORIAL AFRICA
BELGIAN CONGO
NIGERIA
GOLD COAST
LIBERIA
ABYSSINIA
ITALIAN SOMALILAND
KENYA
UGANDA
TANGANYIKA
ANGOLA
RHODESIA
SOUTH-WEST AFRICA
BECHUANALAND
UNION OF SOUTH AFRICA
MADAGASCAR
RIO DE ORO
ERIT
SOM

FIG. 13

MOROCCO

Apart from Egypt, the search for oil on the continent of Africa has been resumed on only a minor scale during 1946, with operations other than geological reconnaissance, confined to French North Africa.

In Morocco, the French Government company continued to exploit the 4 small fields in the inter-montane Taza basin: Tselfat, Bou Draa, Bou Draa Nord, Souk-el-Arba (Ain Hamra). Annual production of about 35,000 barrels remained about the same as before the war; production from the first 3 fields is from the Jurassic; that at Ain Hamra is from the Tertiary. Accelerated drilling and exploration is planned for the future.

ALGERIA

In Algeria, a 3-year program of intensified exploration surveys and deeper drilling was proposed in 1945, to be carried on by a newly formed French Government-sponsored company. Plans for increased geological work and the acquisition of new drilling equipment were reported. In the past, more than 100 relatively shallow wells have been drilled in the small Chelif inter-montane basin, east of Oran, and 3 small fields were found: Ain Zeft, Medgilla, and Messila. To 1914, Ain Zeft had produced 10,000 barrels of oil and the other two, at the end of 1938, had produced 174,000 barrels. Recent figures are not available. The reservoir beds are Tertiary in age.

TUNISIA

Like Morocco and Algeria, Tunisia has also had much sporadic exploration activity in the past, largely in the numerous seepage areas in the north, but no oil or gas fields have been discovered. The French Government's present plans are to greatly expand its exploration effort and extend it southeast, away from the highly disturbed areas. Geophysics and modern drilling equipment are to be used. Though no details are available, it is presumed that surface surveys and some shallow drilling were carried on in the northern region during the past year.

TRIPOLITANIA

The Mediterranean coastal belt extending westward from Egypt through Tripolitania (Cyrenaica and Libya) has been the object of some reconnaissance study in the past.

GABON

The French Government has a program of surface mapping, geophysics, core-drilling, and deep testing under way in the Gabon basin of French Equatorial Africa.

NIGERIA

The Anglo-Iranian Oil Company has recently announced its intention to resume joint exploration with the Shell in the Nigerian basin. The presence of tar

sands along the coast east of Lagos has attracted attention and some drilling was done prior to the war, but no fields have been discovered to date.

ABYSSINIA

As announced in 1945, the Sinclair has been given a concession to explore for oil throughout the country. Basic regional geologic study and aerial photo interpretation have been carried out, but intensive field operations have not yet commenced.

MADAGASCAR

The French Government has under way fairly extensive plans for geological and geophysical work in the western part of the island. Surface indications and more or less sporadic drilling during the past 40 years have proved the petroliferous charaster of the Triassic in several places, but no oil has been produced commercially.

SOUTH AFRICA

The Government of South Africa has spent some money on exploration during the war. Two wells were drilled on the south side of the Karroo basin, where the sedimentary rocks belong to the upper Paleozoic-early Mesozoic Gondwana series. One well, in the Laingsburg district, was drilled more than 9,000 feet in depth with negative results.

TABLE V

WORLDWIDE GEOPHYSICAL ACTIVITY IN 1946 IN CREW MONTHS*

Country	*Seismic*	*Gravity*	*Magnetometer*	*Electrical Prospecting*
Alaska	?	?	?	
Canada	96	13	—	—
United States	4,210	1,650	239	—
Mexico	72	48	—	12
Nicaragua	?	—	—	—
Bahamas	2	40	10	—
Cuba	9½	14	24	—
Dominican Republic	12	—	—	—
Venezuela	341	147.5	14	—
Colombia	138	63	9	—
Ecuador	12	10	—	—
Chile	5	—	—	—
Argentina	72	36	12	—
Paraguay	18	—	—	—
Brazil	24	—	12	—
England	12	4	—	—
Netherlands	—	12	—	—
Germany	30	—	—	—
Hungary	—	—	—	—
Italy	—	2	—	—
Russia	?	?	?	?
Egypt	8	11	—	—
Palestine	5	—	—	—
Syria	—	—	1	—
Cyprus	—	6	6	—
Iraq	7	12	11	—
Trucial Coast	—	6	6	—
Qatar	2	—	—	—
Iran	—	—	—	—
Kuwait	—	—	—	—
Saudi Arabia	—	—	—	—
India	3	—	—	—

* These are minimum figures which are perhaps exceeded in some countries, and a minor amount of geophysical work may have been done in countries not listed.

TABLE VI. WORLD CRUDE-OIL PRODUCTION—BARRELS 42'S
(Partly Estimated)

	Cumulative through 1946	*Daily Average*	
		1939	*1946*
United States	33,223,058,000	3,465,649	4,747,000
Canada	115,986,000	20,664	19,900
Cuba	325,000	—	550
Mexico	2,255,142,000	117,203	135,000
Other North America	406,000	—	—
Total North America	35,594,917,000	3,603,516	4,902,450
Venezuela	3,612,074,000	562,829	1,064,900
Colombia	388,210,000	64,835	60,250
Trinidad	328,369,000	53,541	55,000
Argentina	363,737,000	50,999	56,875
Bolivia	3,479,000	589	1,000
Brazil	258,000	—	200
Ecuador	39,500,000	6,461	6,500
Peru	343,351,000	37,007	34,150
Total South America	5,078,978,000	776,261	1,278,875
Total West. Hem. except U. S.	7,450,837,000	914,128	1,434,325
Total Western Hemisphere	40,673,895,000	4,379,767	6,181,325
Albania	9,213,000	3,027	1,000
Austria	43,912,000	2,580	11,875
Czechoslovakia	3,900,000	325	525
France	14,042,000	1,370	1,100
Germany	84,498,000	12,823	12,525
Great Britain	3,502,000	88	1,125
Hungary	34,603,000	3,069	14,100
Italy	3,199,000	241	250
Netherlands	479,000	—	1,200
Poland*	269,850,000	9,058†	2,200‡
Roumania	1,144,867,000	127,141	86,000
Yugoslavia	2,374,000	—	1,000
Total Europe except Russia	1,614,439,000	159,722	132,900
Egypt	97,823,000	12,796	25,150
Iraq	344,246,000	82,079	96,650
Iran	1,587,993,000	202,611	402,200
Bahrein	77,896,000	20,791	20,000
Arabia	111,644,000	10,778	162,525
Qatar	26,000	—	—
Kuwait	6,889,000	—	18,875
Other Africa	557,000	—	—
Total Near and Middle East	2,227,074,000	329,055	725,400
Burma	282,059,000	21,570	2,000
China	2,922,000	—	2,000
India	49,384,000	6,375	7,000
Japan	93,143,000	6,471	3,925
Total South and East Asia	427,508,000	34,416	14,925
British Borneo	120,797,000	19,383	10,000
Neth. East Indies	1,109,111,000	160,554	25,000
Total Oceania	1,229,908,000	179,937	35,000
Total East. Hem. except Russia	5,498,929,000	703,130	908,225
Total foreign except Russia	12,949,766,000	1,617,258	2,342,550
Russia and Sakhalin*	5,587,132,000	611,319§	450,000‖
Total foreign	18,536,898,000	2,228,577	2,792,550
Total world	51,750,956,000	5,694,226	7,539,550

* Eastern Poland included with Russia commencing 1941.
† Pre-war territories.
‡ Western Poland only.
§ Includes Soviet share of Sakhalin (8,000 barrels per day).
‖ Includes all Sakhalin and eastern Poland (approx. 23,000 barrels per day).

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PALEOGEOGRAPHY OF SOUTH AMERICA[1]

L. G. WEEKS[2]
New York, N. Y.

ABSTRACT

The major features of the geologic framework of the continent are outlined. Attention is called throughout the paper to the many similarities in the continental framework and geologic history of South America with those of North America.

The change in paleogeography and facies from Cambrian to Pliocene inclusive is pictured on 15 paleogeographic facies maps selected to show the principal sedimentary overlaps. Intervening changes and conditions, the progress of transgressions, and the fundamental transitions in the architecture of the continent that caused or conditioned the paleogeographic and facies changes are briefly reviewed.

The major events as interpreted from the stratigraphy, structure, and other features of the geology are the following.

1. Late Proterozoic diastrophism.

2. Upper Cambrian marine transgression and wide-spread late Cambrian—early Ordovician sedimentation, with less extensive deposits of Middle and later Ordovician and early Silurian time.

3. Main Caledonian orogenies of late Ordovician to Silurian, and a general withdrawal of the seas during much of the Silurian. The best developed Silurian seaways, as in North America, are apparently in the eastern part of the continent.

4. Marine advance in late Silurian and Lower Devonian. An extensive development of Lower Devonian sediments, which embrace the major part of the Devonian age sediments of South America. However, a Middle Devonian marine invasion spread through the Colombia-Venezuela and Amazon troughs and southward down the Cordilleran trough at least as far as 20° S. Lat.

5. Upper Devonian sediments are unknown in South America. Mississippian marine sediments occur in the West-Central Argentine embayment and at least locally in the Colombian seaway; and they may yet be found in the Cordilleran trough of Peru and Bolivia, where continental beds of Mississippian and probably also Pennsylvanian ages occur.

6. Mid-Pennsylvanian marine sediments are known locally in the Cordilleran trough, but the first major marine advance following the Devonian began in the late Pennsylvanian and persisted through the early Permian. It covered approximately the same areas that were occupied by Devonian seas. Glaciation occurred south of about 20° S. Lat., and its deposits are interfingered with both marine and continental sediments in the southern areas. Less extensive, mainly continental sedimentation of later, possibly mid-Permian age, locally carrying glacial deposits in the south, rest disconformably on early Permian.

7. Marine sediments of Upper Permian and Lower and Middle Triassic age are not recognized on the continent. Some plant- and coal-bearing beds in Peru are thought to be mid-Triassic.

8. The sea advanced from the west in the Upper Triassic into the basins occupied by Permian sedimentation. The marine sediments interfinger with and change to a continental facies toward the margins of the advance. These continental clastics overlap beyond those of the Permian in many places.

9. A new pattern of geosynclines, whose formation began along the belt of the present Cordillera in the Triassic, is occupied by Jurassic sediments whose main seas existed in the Lias, Bajocian, and Callovian ages. Barred basins developed in these geosynclines. These were sufficiently closed to deposit salt and anhydrite in the Oxfordian stage.

10. A re-advance of the sea in the late Jurassic, Tithonian, spread sediments of Tithonian and early Cretaceous Neocomian stages through somewhat more extended areas of the western geosynclines, opening southward through Tierra del Fuego, and also extending for the first time across the northern part of the continent.

11. In the Aptian-Albian-Lower Cenomanian (Comanche) ages of the Cretaceous the Cordilleran seaways enlarged in the northern and northwestern areas and receded toward the new southern Patagonian embayment. A marine embayment appeared for the first time in the Bahia area of the Brazilian coast.

12. A withdrawal of the seas in the Cenomanian was followed in late Cenomanian and Turonian time by a wide marine advance over the areas of Aptian to early Cenomanian sedimentation. Deposits of this sea are most prominently developed in the Turonian and lower Senonian stages. As a pre-

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[2] Chief research geologist, Standard Oil Company (New Jersey).

liminary to the uplift of the Andes, the over-all slope of the continental platform, which had been largely westerly during the Paleozoic and lower Mesozoic, began to take a more level stand. As a consequence extensive, largely fresh-water lakes spread over the interior of the continent during the Upper Cretaceous.

13. Two or more relatively minor to locally more severe movements affected the continent in the late Cretaceous. The first caused a retreat of the sea in the Upper Senonian. In many parts of South America, as in other parts of the world, a well defined hiatus separates the Tertiary from the Cretaceous. However, the seas advanced into the deeper parts of the troughs and embayments to deposit sediments of late Senonian to Paleocene stages.

14. The first major Andean orogenic movement of the Tertiary occurred in post-Paleocene, early Eocene time. A marine advance followed which spread widely in the middle Eocene, and there were further lesser retreats and prominent readvances in the upper Eocene.

15. A second major Andean movement had its climax in early Oligocene. This was followed by sea advances of middle Oligocene to early Miocene time.

16. The Oligo-Miocene deposits spread headward and inland and continued upward through the middle Miocene into brackish and still more continental facies, while they remained marine in character in more restricted episeas of the continental margins.

17. Upper Miocene brought a further general retreat of seas and a drying-up of interior areas preliminary to a third major Andean orogenic-epeirogenic movement in late Miocene.

18. The seas readvanced into certain local embayments and marginal areas in the Pliocene.

19. Continental deposition continued along the Andean front in the Pleistocene as the fourth major Andean movement raised the Cordilleras to approximately their present conformation. Glaciation developed in the higher mountains and was general over southern Patagonia.

20. Taphrogenic breakdown and general subsidence of continental border areas and belts, which began in the Mesozoic, became more pronounced in the late Tertiary and Quaternary.

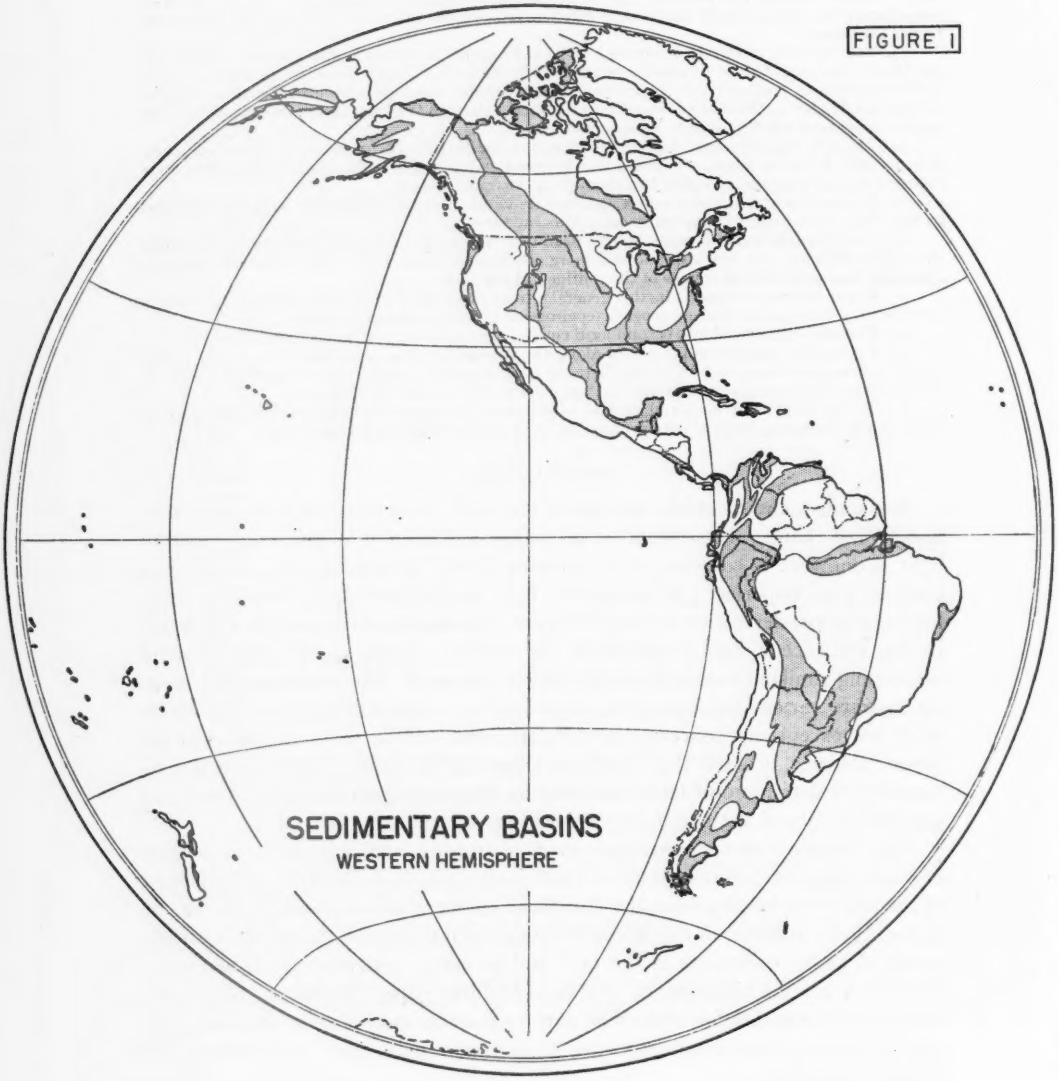
INTRODUCTION

Our understanding of the geology of the earth or any part of it is constantly undergoing change. This condition of change and growth as new facts come to light is one that is common to all sciences. Every geologic map is, in effect, a progress map, imperfect and vulnerable. Paleogeographic maps of South America for 20 principal deposition overlaps or units of sedimentation from the Cambrian to the Pleistocene were prepared by the writer 7 years ago in the course of developing similar broad regional studies of the earth. The accompanying maps incorporate various subsequent revisions and no doubt will require many more. With few exceptions, concerned particularly with certain parts and areas of the lower Paleozoic, it is felt that future revisions will be more in the nature of a refinement of detail and of facies distribution than in respect to the existence and general outlines of the major seaways and embayments.

The compilations are based on 22 years of growing familiarity with the geology of South America, about 15 years of which were spent in field study of many parts of the continent ranging from the Caribbean on the north to Tierra del Fuego on the south. In addition to this first-hand source of information the writer is greatly indebted to his colleagues in the field and to many sources of published information. A selected bibliography of several hundred papers, books, and other publications is appended for those who care to enquire more deeply into the geology of the continent. No doubt other good papers exist that have escaped the writer's attention.

The writer is not a paleontologist. Hence he is much indebted to the paleontologists, particularly to those who are also stratigraphers and who are able to rationalize their findings by fitting them into the broad regional picture of stratigraphic similarities and facies changes and the fourth dimension, geologic time.

FIGURE 1



There is no area of the earth, large or small, and no problem in geology that can not be better understood when it can be visualized against a broader background.

In covering a subject as vast as that here involved within the limits of space and time available, only the barest outline can be presented. The paleogeographic maps are selected to picture the principal units of sedimentary overlap or "layers of geology." These chapters are fitted into the geologic story of the continent after we take a brief look at the continental framework with the aid of Figure 1, which shows the present structural (in contrast to original sedimentary) basin areas of the two Americas.

CONTINENTAL FRAMEWORK

The geologic framework of the continent of South America bears many similarities to that of North America. Chief of these are the following.

1. The right-angle triangular shape.

2. The great central stable shield or continental nucleus—Canadian shield in North America and Brazilian shield in South America, each covering a vast area in the northeast-central part of the continent.

3. The long mobile belt, consisting of asymmetric geosynclinal troughs and borderlands, which fringed the forelands of the stable shield areas on the west throughout most of geologic history and which, through a series of orogenies, developed into the lengthy Cordilleras of to-day.

4. The development of mobile belts, now marked by the southwest-trending so-called Brazilides of eastern Brazil and the middle Argentine ranges, that are broadly similar in respect to position, age, and trend, although on a very much lesser scale of development, to the Appalachian-Ouachita-Llanoria belts in North America.

5. The remarkable similarity of the West Indian arc, connecting North and South America through southern Mexico, northern Central America, the Greater and Lesser Antilles, and the northern Trinidad and Venezuelan coast ranges, with the southern arc which connects Antarctica with South America through Tierra del Fuego, Burdwood, South Georgia, South Sandwich, South Orkneys, South Shetlands, and the Antarctides. (It is evident that the connection between the two continents through Central America is not that of the ordinary tectonic mobile belt of the crust. As just stated, the tectonic mobile belt connection clearly follows the arc of the Antilles into its Andean continuation in South America. The more direct connection through Central America is rather clearly that of a volcanic bridge across the easterly embaying Pacific-Caribbean plate. The basic lavas forming that bridge and the similar lavas comprising part of the foundation of the Antilles rose incidental to the collapse of the Pacific-Caribbean areas. This collapse and the extravasation of the basic volcanic lavas to form the bridge occurred since the Cretaceous, just as the thousands of Tertiary-Quaternary volcanic islands and island ridges throughout the Pacific region rose during the same period which, on balance, was one of subsidence of the ocean plate.)

6. The similar spread of seas over the forelands and interior shield areas at similar periods from the major troughs and seaways that lay in the main on the west and southwest. Seas entered also at certain periods on both continents from the northeast and/or northwest.

7. The similar changes in general pattern of the paleogeography (shown on the accompanying maps in the case of South America) from that of the Paleozoic to that following the Triassic. On both continents new Mesozoic-Tertiary geosynclines opened along the backs or hinterlands of the Paleozoic mobile belts, extending from beyond Japan through southern Alaska and through western North and South America.

8. The high plateau-like widening and westward bulge in the region of the middle Cordilleras on both continents.

9. The marine overlaps of Cretaceous-Tertiary age from the east and southeast on both continents. These overlaps developed with the uplift of the Cordilleras, which brought about a change in the over-all tilt or surface slope of both continental blocks from the westerly one that was generally prevalent prior to the Cretaceous to an easterly or southeasterly slope subsequent thereto.

10. The subsidence, largely occurring during the period from late Cretaceous to the present, of the hinterland belts of the Cordilleras beneath the waters of the Pacific along the coasts of both contiennts.

Numerous other similarities exist, many of which will be mentioned. However, there are differences of interest. One is the fact that, with few exceptions, the extent and the depth of epeiric seas was somewhat less in South America than in North America. Likewise marine conditions in South America were less prevalent or continuous and there was a lesser volume of sediments left by the seas than in the northern continent. Another difference is the fact that, relative to North America, there is a very low representation of carbonate rocks in the basin sediments.

ALGONKIAN

Deposits of the Algonkian or late pre-Cambrian are difficult to differentiate in many cases. The picture is obscured by the fact that sediments of many ages up to even Triassic, Jurassic, and Cretaceous have been called pre-Cambrian at one time or another. Usually considered a part of the Algonkian are a series of highly metamorphosed sediments, including huge deposits of high-grade iron ore, deposited in an ancient north-northeast trending geosyncline in eastern Brazil. Other iron-ore deposits occur in Venezuela south of the Orinoco. These occurrences recall that of the Lake Superior iron ores of similar age. Southward along the same trend in Brazil and Uruguay, in northern Paraguay, in southwestern Matto Grosso, and in the Andean belt of northern Argentina, Peru, and Bolivia occur old metamorphics which have been considered as pre-Cambrian in age but part of which may very well be younger. Other local occurrences, particularly in southern Brazil and Uruguay, sometimes placed in the early Paleozoic, fit more logically in the late pre-Cambrian.

CAMBRO-ORDOVICIAN

As in North America the widest extent of the Cambrian seas was in the upper or late Cambrian. In fact, no lower Cambrian has been identified in South America. Latest Cambrian and/or lowermost Ordovician marine sediments are known in the Macarena and neighboring parts of south-central Colombia. Ordovician is present in the Merida Range of western Venezuela, at Puerto Berrio in the Magdalena valley of Colombia, and seems to be also represented at other places in northern Colombia. An Ordovician age is probably represented in the early Paleozoic sediments of southern Ecuador.

Middle and, particularly, Upper Cambrian marine sediments are known along the eastern Cordillera of Bolivia. This marine invasion transgressed southward into northern Argentina where it embayed in a less marine facies. Transgression continued in the Ordovician in the Cordilleran and pre-Cordilleran belt of Argentina, Bolivia, and Peru.

Various marine advances and retreats are indicated, but the principal Ordovician occurrences are lower and Middle Ordovician in age. Consisting largely of graptolite shales in the north, there is a change to a more sandy facies southward; while farther south, in the somewhat detached San-Juan-Mendoza area of west-central Argentina, where the beginning of a Paleozoic connection with the Pacific apparently existed, there occurs a well known calcareous facies.

Cambrian faunas of the Cordilleran belt are said to show affinities particularly with the Pacific North American province, but rather early in the Ordovician faunas appear which indicate affinities with Atlantic-European waters. Possibly connections existed from the north through the Caribbean, from the east across a developing Amazon geosyncline, and across the middle of the continent through Brazil where early Paleozoic sediments of still insufficiently defined age occur.

In 1942 Middle Ordovician graptolite shales were identified in the center of a domal uplift in northeast Peru near the Brazilian frontier, further suggesting that the Amazon Paleozoic geosyncline may have developed this early in the Paleozoic era. Indeed, the 1938 geologic map of the Ministry of Agriculture of Brazil shows the oldest sediments of the Amazon trough as questionably late Cambrian and they similarly map large areas of still insufficiently studied sediments extending across middle and eastern Brazil. Wherever early Paleozoic sediments are present in many parts of the world the Ordovician is commonly prominent. For this reason and also from the fact that the Ordovician seas were more widespread than the Silurian or post-Caledonian seas in other parts of South America, it is felt that the Ordovician will be found represented in many of the occurrences of pre-Devonian age in Brazil.

Some of the older sediments of Brazil and Uruguay, occasionally mapped as early Paleozoic, may be late pre-Cambrian. However, it is the writer's opinion that, in the absence of recognizable fossils, geologists in general are apt erroneously to ascribe too great an age to sediments that show a high degree of metamorphism. This error has been made in South America with respect to highly met-

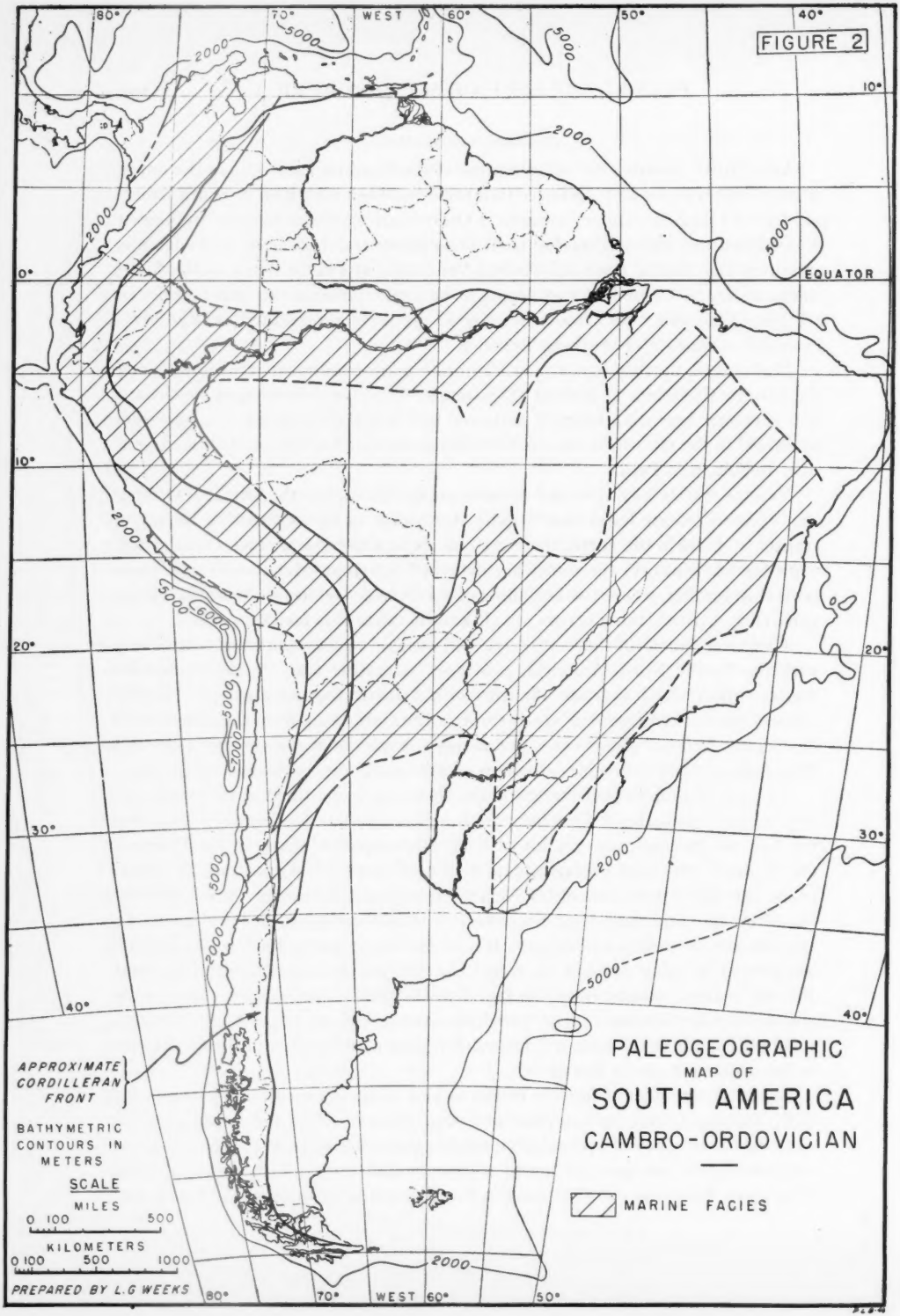


FIGURE 2
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PREPARED BY L.G WEEKS
PALEOGEOGRAPHIC
MAP OF
SOUTH AMERICA
CAMBRO-ORDOVICIAN
MARINE FACIES

amorphosed sediments, even as young as the Cretaceous, where these happen to occur in a belt that once was highly mobile.

No paleontologic evidence of Paleozoic deposits has yet been found in the Patagonian Andes or at any other place in South America south of 38° S. Lat. But in the South Orkneys, about 700 miles southeast of Cape Horn, Middle Ordovician species of arthropod and of graptolite are reported to occur in sediments that have been altered to slates.

SILURIAN

It is principally the lower and the very latest Silurian that is found in South America. The early Silurian is present in the deeper parts of the Cordilleran seaway, particularly in Peru and Bolivia, as a continuation of the Ordovician graptolite-bearing sediments. It also occurs in the lower Amazon trough where it had possible connections westward, as shown, with the seas of the Cordilleran belt.

The extensive Bambuhy and older series of east-central Brazil have, by some, been considered Silurian in age, based on a very meager and insufficiently studied fauna. The writer feels certain on the basis of paleogeographic, stratigraphic, lithologic, and structural considerations, that these series are pre-Devonian. They may very well be Lower Silurian or Ordovician in age, or both. The paucity of fossils may be in part due to a semi-flysch character of much of the sediments, which were probably largely derived from the eastern mobile borderland and hinterland belt.

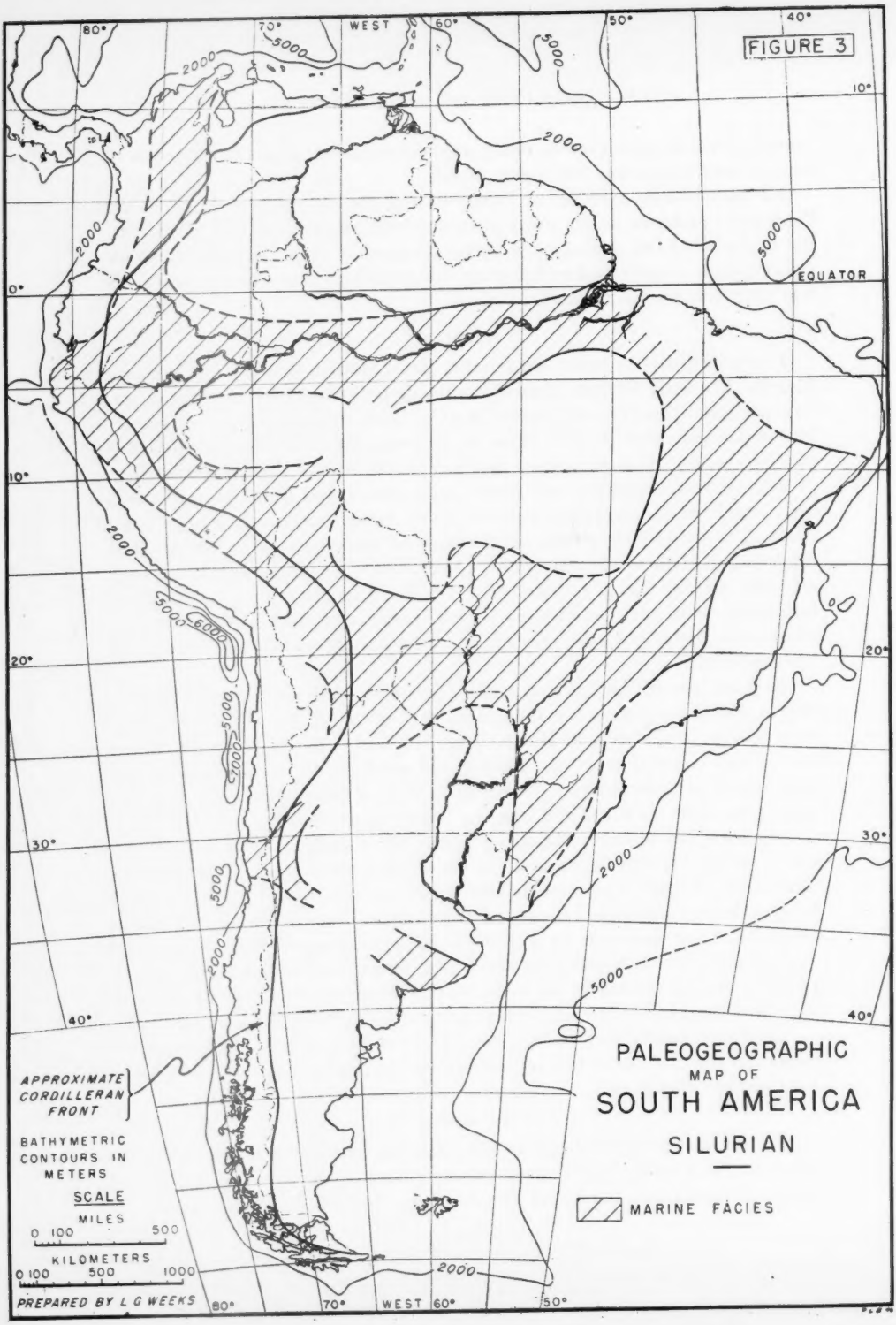
As is the case in North America, the Silurian of South America may have its best or widest development in the eastern part of the continent. Sediments possibly Silurian in age occur in Matto Grosso and westward. There are indications of a possible connection between the Amazon and Cordilleran troughs across the Beni area of northern Bolivia. The extension of the Silurian seaway shown on the map across southern Brazil and Uruguay is very questionable.

The sea appears to have withdrawn extensively or completely from the present area of South America during much of the Silurian, probably in response to the Caledonian (Taconic) movements that so widely affected the earth. In latest Silurian time a readvance of the sea occurred which continued through the Lower Devonian. These sediments occur in the Cordilleran trough of Peru, Bolivia, and Argentina and in the trough then developing across middle Argentina, and they probably are represented in the eastward transgressive advance of the Bolivian sea across Paraguay toward the Parana basin of south Brazil and north Uruguay.

There are insufficiently confirmed indications that Silurian sediments are present in the Cordilleran belt of Colombia in the same trough belt occupied by the Cambro-Ordovician.

DEVONIAN

The sea advance which began in latest Silurian time spread eastward through the Chaco and Parana basin areas and along the middle Argentine seaway and remained throughout the Lower Devonian. In the Cordilleran trough area of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MAP OF
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BATHYMETRIC CONTOURS IN METERS
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PREPARED BY L G WEEKS

Bolivia and south Peru thousands of meters of flysch-type sediments accumulated. These were derived from lands newly raised by the Caledonian orogenies. In Bolivia and Peru sedimentation extended into the Middle Devonian. As a result of the Caledonian deformation in central Argentina the Cordilleran Devonian sea did not extend as far southward as did that of the Ordovician. In Brazil the Devonian consists of a prominent basal sand, overlain by shales which become somewhat more sandy at the top. Devonian sediments of South America are largely clastics, shales, and sands. The Lower Devonian sea spread also through the Amazon trough, and far toward the south it covered the Falkland Islands.

In addition to its occurrence in the central Cordilleran area, Middle Devonian is also present in the Amazon trough; and only Middle Devonian has so far been recognized in the Colombia-Venezuela trough, where, however, the occurrences are fairly widely distributed. Middle Devonian has not been recognized south of 20° S. Lat., unless a sandy facies which conformably overlies the lower Devonian shales in the Bolivian pre-Cordillera is of that age. Very recently field studies in the Maranhao basin, shown on the Devonian and on the Upper Carboniferous-Permian maps extending southward from the area of the mouth of the Amazon, revealed the presence of a Devonian marine fauna; hence, a Devonian embayment apparently extended into this area.

Lower Devonian faunas of all basins south of the Amazon basin have a characteristic, related austral or southern aspect. The Amazon basin Lower Devonian sediments contain a similar fauna but with an admixture of northern forms. The Middle Devonian of Colombia, of the Amazon basin and of Bolivia, while varying in ecologic conditions, all contain a related and essentially northern fauna, though in Bolivia there are thought to be present certain descendants of southern Lower Devonian types.

Upper Devonian time apparently found the seas withdrawn everywhere, though limited deposits of that age may yet be found in the areas of Middle or earlier Devonian sediments, especially in the troughs of greatest subsidence.

MISSISSIPPIAN

After the withdrawal of the Devonian seas from the area of the present continent South America remained above sea-level throughout the Mississippian period. Recently well developed Mississippian marine sediments have been identified in San Juan and Mendoza in the embayment that extends eastward into west-central Argentina. As we have seen, this was a more or less continuous embayment. Pentremites and other Mississippian marine fossils have been reported in north-central Colombia.

In the Cordilleran belt of Peru and Bolivia sediments are present which are thought to be Mississippian in age. These appear to be largely continental in facies, but it appears not improbable that marine representatives will be found in the deepest parts of the belt of sedimentary troughs. An occurrence of question-

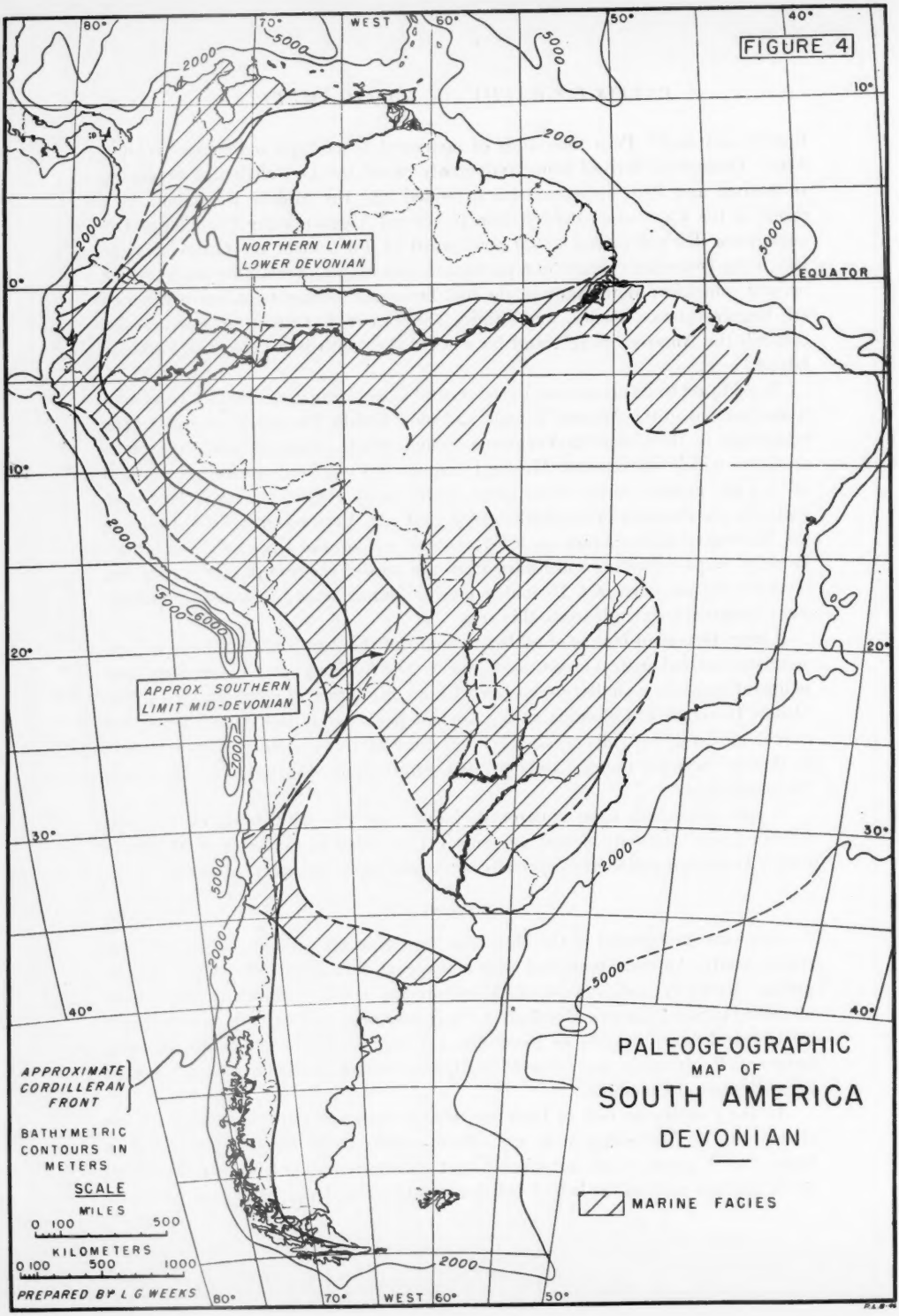
FIGURE 4
NORTHERN LIMIT LOWER DEVONIAN
APPROX. SOUTHERN LIMIT MID-DEVONIAN
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APPROXIMATE CORDILLERAN FRONT
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PREPARED BY L G WEEKS
PALEOGEOGRAPHIC MAP OF
SOUTH AMERICA
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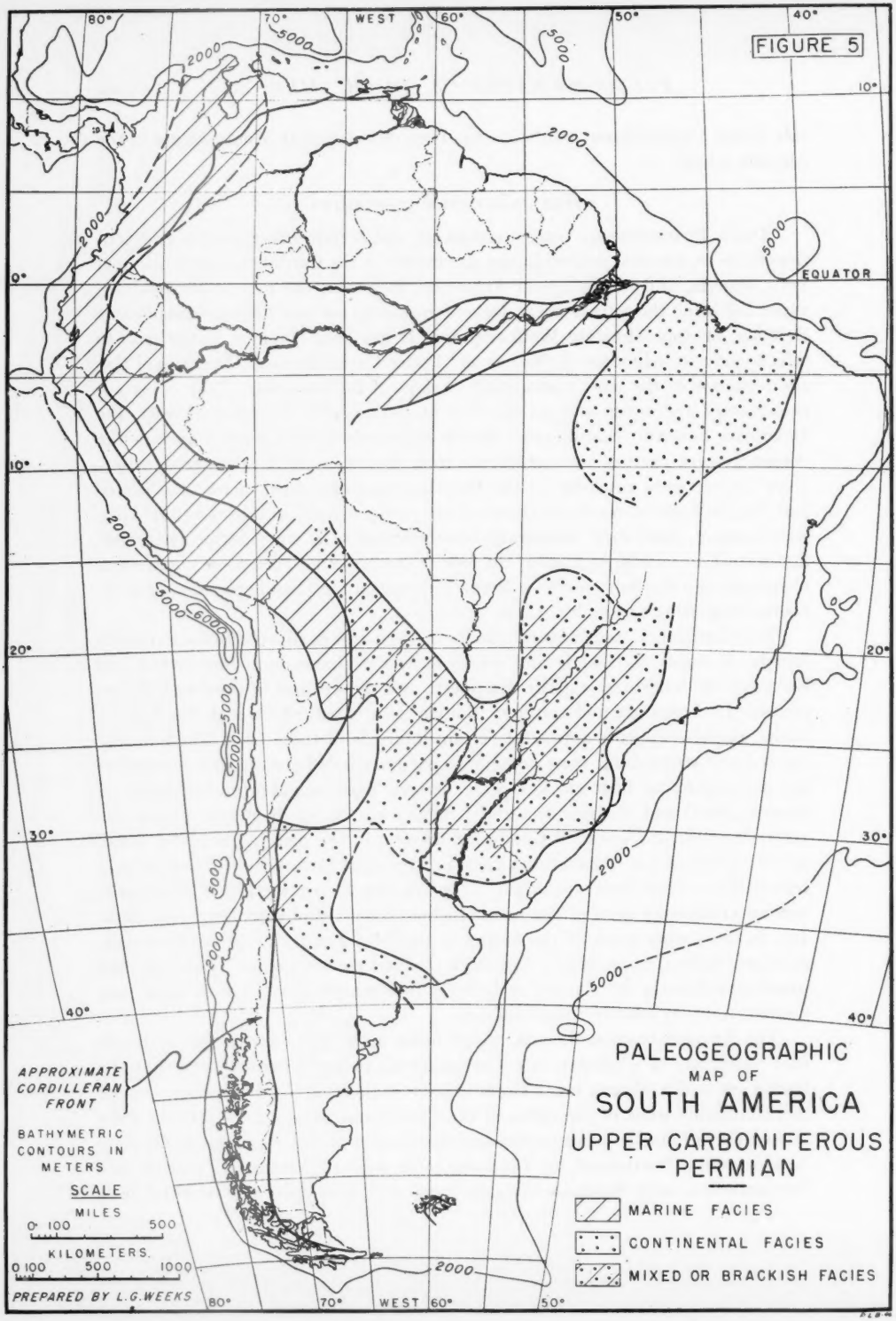
able Lower Carboniferous sandstone has been reported near Monte Alegre in the Amazon trough.

UPPER CARBONIFEROUS-PERMIAN

Middle Pennsylvanian marine sediments and certain other marine and continental beds, less well defined in age, are known in the Cordilleran geosyncline of Peru, Bolivia, and northernmost Argentina. However, the first widespread advance following the retreat of the Devonian seas was of late Pennsylvanian-early Permian, or approximately Wolfcamp age. It has been common in the past to refer loosely to sediments of this age as "Upper Carboniferous." Deposits of this age form one of the most widespread overlaps of the continent. They cover approximately the same area as did the Devonian seas. In contrast with the Devonian, however, continuously marine sediments were deposited only in the deeper western parts of the Cordilleran troughs and in the Amazon geosyncline. Over the eastward extension of the Peru-Bolivia embayment, across the Chaco and Parana basin areas the sediments have partly a continental-sea to brackish-water aspect, with only temporary intercalations of a true marine character. Southward, in middle Argentina, the formations are of an even more continental character, and the only marine sediments appear in the Cordilleran area of west-central Argentina and middle Chile.

The Cordilleran trough marine facies of Peru and northwest Bolivia consists largely of shales and sands and *Fusulina*-bearing limestones. Southward and eastward the limestones rapidly disappear, and the amount of sand and silt increases. In Argentina and southern Bolivia, and eastward through the Parana basin, glacial sediments appear at certain intervals in these beds. These locally faceted and striated but more commonly partly rounded constituents, as well as the accompanying finer clastics, were derived from neighboring highlands of eastern Brazil and of Argentina and Uruguay on the south, where glaciers developed in this, the so-called Gondwana ice age. In the marginal areas of Brazil and Uruguay and in the southern areas in Argentina these sediments are largely terrestrial or fresh-water in origin. They contain the characteristic *Gangamopteris* or Gondwana flora of the southern hemisphere, and associated coal beds. But in the deeper parts of the basins in southern Brazil, Uruguay, Paraguay, southern Bolivia, and northern Argentina the clastics were carried by streams and sometimes directly by glaciers or icebergs into waters that were in large part marine, and they contain a marine fauna.

The Amazon basin sediments, which make up a large part of the section in that basin, are of a similar, late Carboniferous to early Permian age, but the faunas are said to show a much closer affinity to those of North America, though still containing some of the forms of the Cordilleran trough. In northwest Peru and southern Ecuador occur marine shales and other sediments of this age in good development. Northward, in Colombia and western Venezuela, marine late Carboniferous-early Permian is locally very well developed. Continental beds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PREPARED BY L.G.WEEKS
PALEOGEOGRAPHIC MAP OF
SOUTH AMERICA
UPPER CARBONIFEROUS - PERMIAN
MARINE FACIES
CONTINENTAL FACIES
MIXED OR BRACKISH FACIES

also occur which contain the remains of a land flora. Far toward the south, Carboniferous continental glacial deposits overlap the Devonian in the Falkland Islands.

A controversy has long raged over the age of the Gondwana glacial deposits of South America. Some have preferred to place them in the late Carboniferous, others in the mid-Permian. In Bolivia and Argentina and in Paraguay, Uruguay, and Brazil there is a later series of Permian beds which we believe may be mid-Permian or approximately Leonard in age, which is also the age given for some post-Wolfcamp Permian marine beds locally present in Peru and in Colombia. These later sediments of Brazil and other southern areas were deposited in an interior sea of similar outline to that of the earliest Permian, but they are most predominantly of fresh-water character. In many places over the areas these deposits are seen to rest disconformably on the older Gondwana sediments without noticeable difference of dip. In Brazil and adjoining areas a widespread zone of pyrobituminous shales, generally known as the Iraty shales, occurs in these deposits. In numerous outcrops in Argentina and southernmost Bolivia well faceted and striated clastics of a distinctly glacial origin occur approximately near the middle of this upper series and prove the existence of a second period of glaciation in those areas.

TRIASSIC

By the close of the Paleozoic the seas had completely withdrawn from the area of the continent and do not appear in evidence again until Upper Triassic (Keuper) time (Carnian and Norian stages). Some plant- and coal-bearing deposits in Peru have been considered mid-Triassic. In South America then, as in North America and many other parts of the world, the most widespread deposition occurred in the Upper Triassic.

Marine Upper Triassic of the Carnian and Norian stages occur in limited development in southern Ecuador, Peru, and Bolivia. No Triassic marine deposition is known in South America below these stages. The most characteristic marine Triassic formation is a limestone which is locally bituminous and commonly dolomitic and cherty, with silicified fossils and nodules. Eastward and southward (and to a much greater extent than in the late Carboniferous-early Permian) the Upper Triassic sediments become continental.

Marine intercalations of thin limestones, together with marls, silts, and shales occur in the upper Passa Dois of the Parana basin of Brazil and Uruguay. There has been much controversy over the age of the Passa Dois. It is a perfectly conformable sequence. Yet, while the lower part has always been recognized as Permian some of the marine intercalations above were definitely considered to be Upper Triassic on the basis of the contained faunas. A recent restudy of these faunas in Brazil has resulted in the conclusion that they are Permian and not Upper Triassic.

Definitely established Upper Triassic sediments disconformably overlie the zone of marine intercalations. These consist of silts and sands, and the Triassic

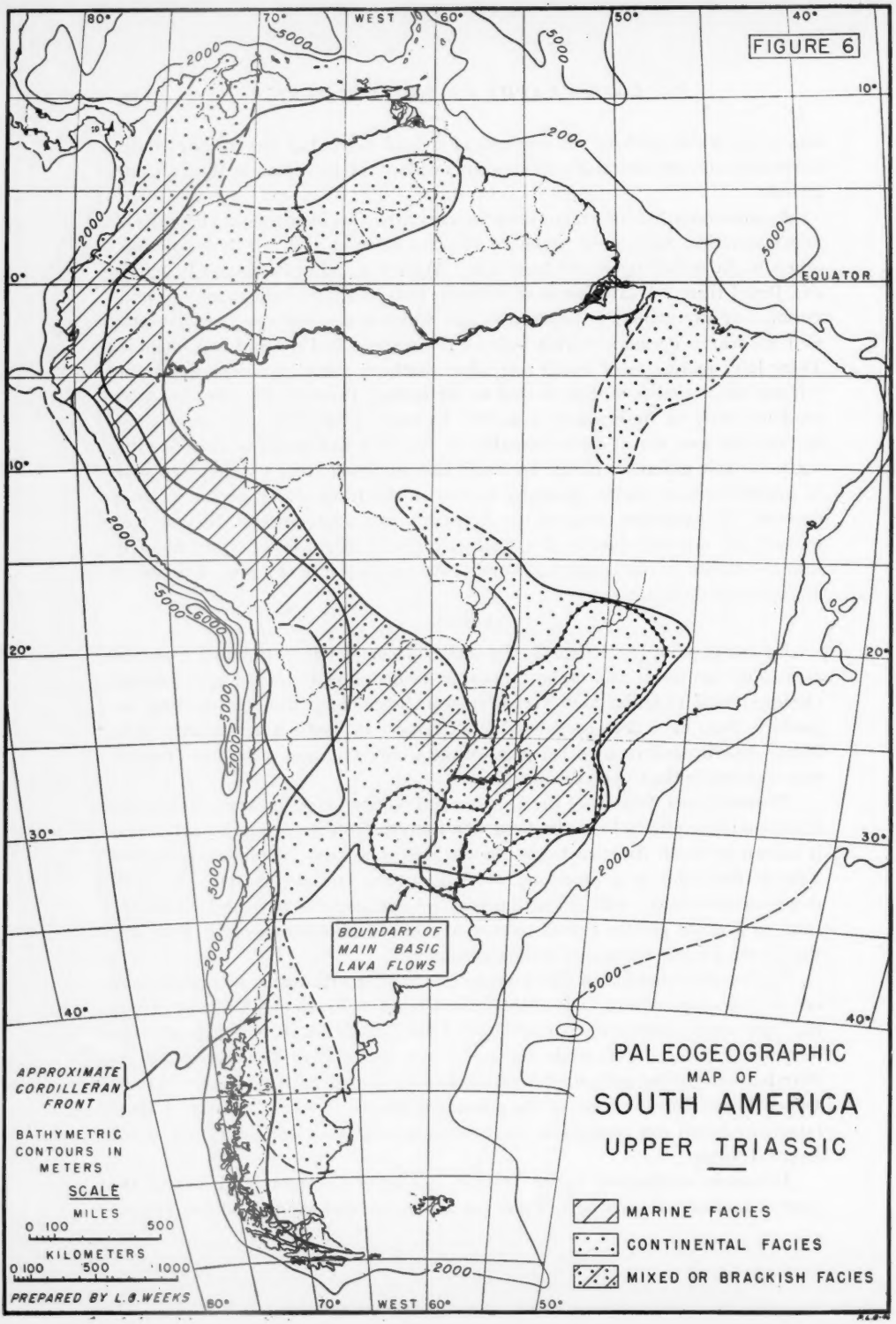
FIGURE 6
80°
70°
WEST
60°
50°
40°
10°
0°
10°
20°
30°
40°
2000
5000
6000
EQUATOR
BOUNDARY OF MAIN BASIC LAVA FLOWS
APPROXIMATE CORDILLERAN FRONT
BATHYMETRIC CONTOURS IN METERS
SCALE
MILES
0 100 500
KILOMETERS
0 100 500 1000
PREPARED BY L.G. WEEKS
PALEOGEOGRAPHIC MAP OF
SOUTH AMERICA
UPPER TRIASSIC
MARINE FACIES
CONTINENTAL FACIES
MIXED OR BRACKISH FACIES

sequence closed with a widespread heavy-bedded sand deposition. Extensive basic flows are intercalated in the upper part of and follow this prominent sandstone. The Triassic of Brazil contains a flora and a reptilian fauna which indicates its Upper Triassic age.

In central and western Argentina Triassic continental sands and other clastics disconformably overlie and, in some areas, overlap beyond the Permian deposits. These continental clastics grade westward into marine Upper Triassic sediments of the Chilean trough. As shown by the maps, this trough was now becoming more prominent, and it continued so through the Jurassic and much of the Cretaceous. The Triassic fauna of South America appears to be mostly of a Pacific character and is related to the western Trias of North America.

No marine Triassic is known north of southern Ecuador. However, northward, in Colombia and western Venezuela, certain red and varicolored clastics, commonly referred to as the Giron series, probably are in part Upper Triassic in age. Characteristically, these sediments contain volcanic lavas and tuffs, as do so much of the late Triassic rocks of South America, and as do many of the westernmost deposits of North America.

In British Guiana, southern Venezuela, and adjoining parts of Brazil occur the prominent Roraima sandstone mesas with associated basic lavas. These sandstones are similar to the widespread late Triassic sandstones of central and southern Brazil; and the associated trap flows in the various areas are mineralogically similar. It is believed that the Roraima sandstones, as well as certain similar mesa-forming sandstones on the west in Colombia are, accordingly, Upper Triassic in age, though they may be somewhat younger.

The volume of the basic, but ordinarily olivine-free trap flows centering in south Brazil is probably the largest recorded on present lands in the earth's history. The main part of these flows spread over a maximum width of nearly 1,000 kilometers and a length of fully 2,000 kilometers. They cover much of southern Brazil, eastern and southern Paraguay, northern Uruguay, and northeastern Argentina in thicknesses ranging from 100 to more than 1,000 meters. The flows are of similar age and mineralogic type as the Palisade flows of the Hudson River and certain other Triassic basalts of the western hemisphere.

Widespread in west-central and southern Argentina and adjacent Chile occur other Triassic igneous extrusives of a less basic character. These include porphyritic rocks, so-called keratophyres, melaphyres, and their equivalent tuffs. Not all of these are Triassic in age for this type of intrusive and extrusive activity continued in the Jurassic and even somewhat later along the Andean mobile belt.

The marine and fresh waters withdrew at the end of the Noric. Continental deposits in north Mendoza and adjacent areas of west-central Argentina, long considered to be Rhaetic in age, are now thought to be eastward equivalents of the Upper Triassic marine sediments that lie in the deeper basin on the west. The same may be true of most of Triassic continental deposits that occur widely in Argentina south of 27° S. Lat.

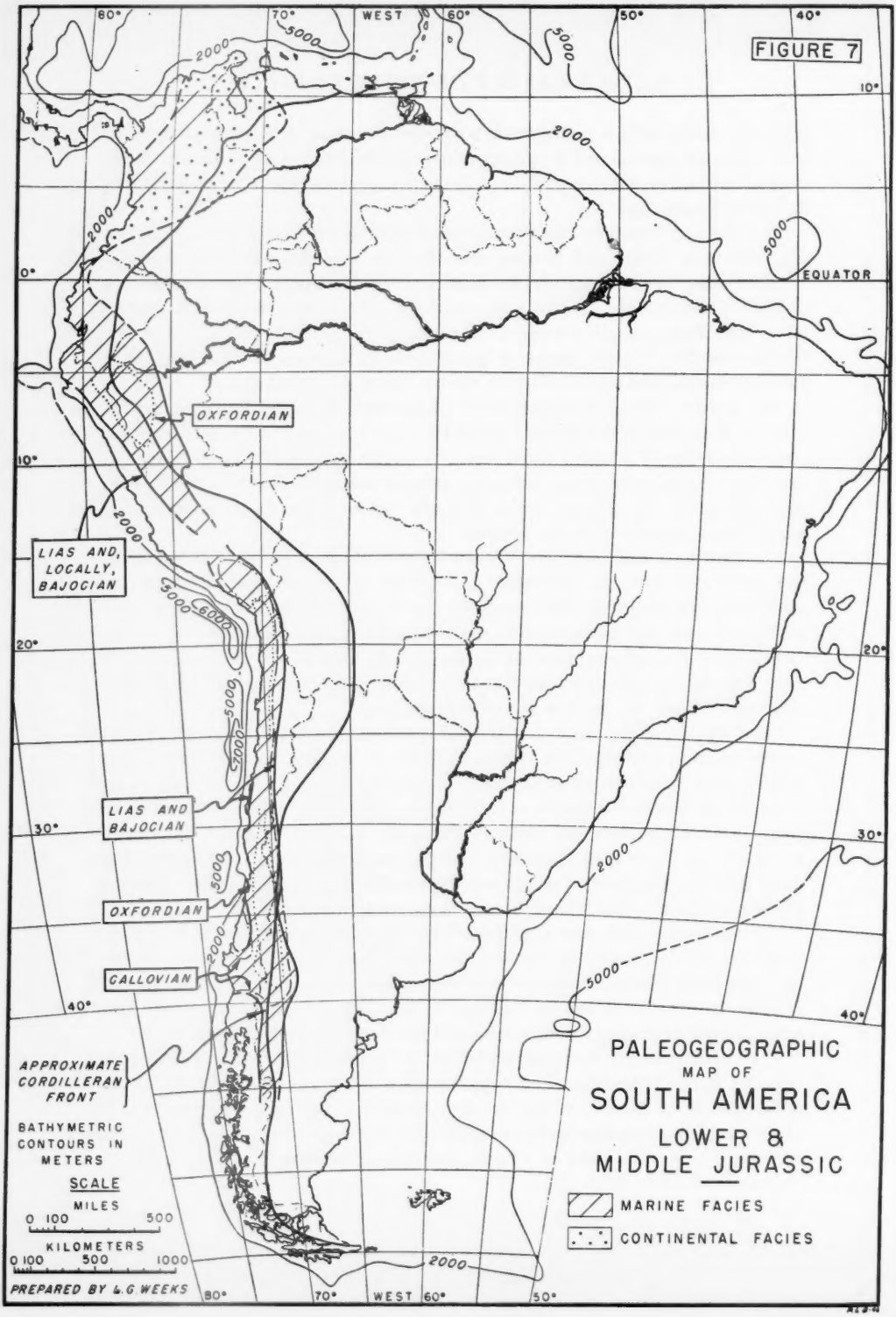
FIGURE 7
80°
70°
WEST
60°
50°
40°
10°
0°
EQUATOR
2000
5000
6000
OXFORDIAN
LIAS AND, LOCALLY, BAJOCIAN
20°
LIAS AND BAJOCIAN
30°
OXFORDIAN
CALLOVIAN
40°
APPROXIMATE CORDILLERAN FRONT
BATHYMETRIC CONTOURS IN METERS
SCALE
MILES
0 100 500
KILOMETERS
0 100 500 1000
PREPARED BY L.G. WEEKS
PALEOGEOGRAPHIC MAP OF
SOUTH AMERICA
LOWER & MIDDLE JURASSIC
MARINE FACIES
CONTINENTAL FACIES

LOWER AND MIDDLE JURASSIC

In South as in North America, and indeed in other parts of the world, the close of the Paleozoic and the opening of the Mesozoic brought a withdrawal of the extensive marine waters, together with an increase in continental deposition. At the same time there was initiated a new pattern of geosynclinal development which we see in the gradual change toward the Jurassic and later paleogeographies.

By Lower Jurassic (Lias) time the new Chilean geosyncline, which shows development on the Triassic map and even earlier, attained prominence. It extended for a distance of 30° of latitude, or from about 15° to 45° S. Lat. The geosyncline was much wider than that shown on the map, which reflects the effect of the considerable post-depositional folding of the Andes. It is not certain, but possible that the Chilean geosyncline connected with that shown on the north in Peru.

Deposition was not continuous in the Chilean and Peruvian geosynclines during the Jurassic. Lias shales and limestones covered the greater part of the areas outlined. There was some withdrawal of the seas in the upper Lias, particularly in Peru. Marine Lias is known at El Banco in Colombia. This sea probably extended in along the main western trough of the embayment. The continental Giron beds in Colombia and equivalent beds in Venezuela, already referred to in connection with the Triassic, are thought to also include sediments of Jurassic age.

The sea readvanced in the Bajocian age of the lower Middle Jurassic (Dogger) over the greater part of the Lias areas of Peru and Chile and appears to have overlapped beyond the Lias in northern Chile and southern Peru. The seas then retreated again, with the result that the upper Dogger, Bathonian stage of the Middle Jurassic, is completely lacking, at least as a marine facies.

A re-advance in the Callovian age received Callovian stage limestones and shales over all of the northern and much of the middle and south-central parts of the Chilean geosyncline. Callovian sediments are not definitely recognized in Peru. If they were deposited there, as seems quite possible or likely, they may have been largely eroded during the diastrophisms that followed.

The moderate orogenic movements which caused the several marine recessions from late Triassic time onward were followed at the close of Callovian time in the Upper Jurassic by more severe orogenic movements. These led first to a closing off of extensive areas of the sea and the deposition of much anhydrite and/or salt and associated sediments in both the Chilean and Peruvian basins during the Oxfordian age. The extravasation of much volcanic material on the western side of the Chilean trough may have been partly responsible for the isolation of that basin. It is of interest, that salt and other precipitates of approximately Oxfordian age occur in Colombia, the Isthmus of Tehuantepec, the Gulf Coast of North America, and in the Mississippi Valley, in addition to the occurrences in Chile, Argentina, and Peru, and in the other parts of the world.

Corallian and Kimmeridgian stage sediments appear to be largely or com-

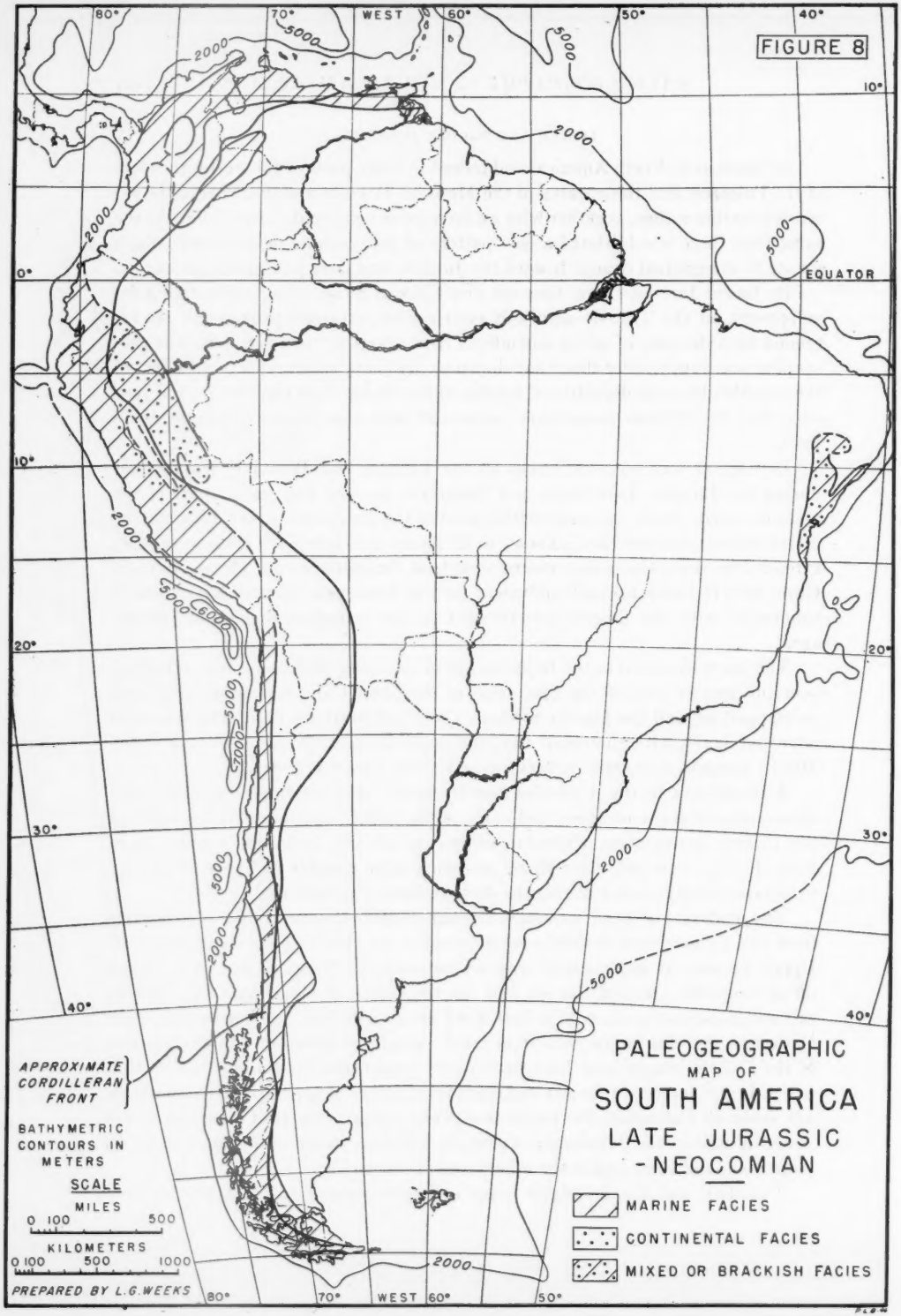
FIGURE 8
80°
70°
WEST
60°
50°
40°
10°
0°
10°
20°
30°
40°
2000
5000
EQUATOR
APPROXIMATE CORDILLERAN FRONT
BATHYMETRIC CONTOURS IN METERS
SCALE
MILES
0 100 500
KILOMETERS
0 100 500 1000
PREPARED BY L.G.WEEKS
PALEOGEOGRAPHIC MAP OF
SOUTH AMERICA
LATE JURASSIC -NEOCOMIAN
MARINE FACIES
CONTINENTAL FACIES
MIXED OR BRACKISH FACIES

pletely absent in the geosynclines, though representatives of these stages may later be found. The most severe of the Jurassic orogenic movements occurred in late Jurassic, possibly Kimmeridgian time. This corresponds roughly with the so-called Nevadan revolution of North America. Various low arches, principally along the eastern Cordillera of Peru developed at this time.

As in western North America, the close of the Jurassic in the Portlandian or Tithonian age witnessed an extensive readvance of the seas, and a deposition that continued on through the early Cretaceous. The paleogeography of the Tithonian is shown along with that of the Neocomian on the next map.

TITHONIAN-NEOCOMIAN

The transgression which began in the Tithonian or closing stage of the Jurassic continued into the early Cretaceous. The paleogeography of the Tithonian and the paleogeography of the early Cretaceous (Neocomian) are essentially similar. Except for certain limited deposition breaks in Peru and possibly other places, they may be treated as a unit. This unit has its approximate counterpart in the Pacific belt of North America, in Mexico, in the subsurface of the lower Mississippi Valley, in the Wealden of England, France, and Spain, and in other regions.

In the Chilean trough, Tithonian brown and black shales and limestones are followed conformably by Neocomian shales, limestones, and sandstones. Most of this sequence is marine. During the period the trough rapidly extended southward from northern Patagonia and probably northward through Tierra del Fuego, permitting ingress of southern faunas and mixture with the Indo-Pacific faunas that prevailed at this period along the west coast of the Americas. Paleozoic and early Mesozoic marine sediments have not been definitely recognized in southern Patagonia or on Tierra del Fuego. Just as they do in the north Venezuelan Andes, the Cretaceous formations appear to transgress directly upon the crystalline basement, though local occurrences of older sediments may one day be identified in the south Patagonian Andean belt.

In Peru marine sediments of the period occur in good development on the coastal belt in the region of Lima. Here the Valanginian and Hauterivian stages of the Neocomian are particularly well represented. Eastward, toward the late Jurassic arch or arches, which, as already pointed out, developed along the belt of the present eastern Cordilleras, there is a change to a mixed marine and continental facies bearing some coals. In northern Peru, still little known coals of this age occur, which may rank among the most important in volume and quality in South America. The earlier Tithonian, largely marine facies is best represented in the northern and northwestern part of the geosyncline, while it is mainly the Neocomian that extends into the upper part of the embayment south of 9° S. Lat. East of the Eastern Cordilleran arch the Tithonian also thins out southward, and the Neocomian appears to consist largely of continental red or varicolored clastics, including much cross-bedded, possibly in part windblown, sandstones.

The late Jurassic-Neocomian sea of Colombia also spread eastward from the

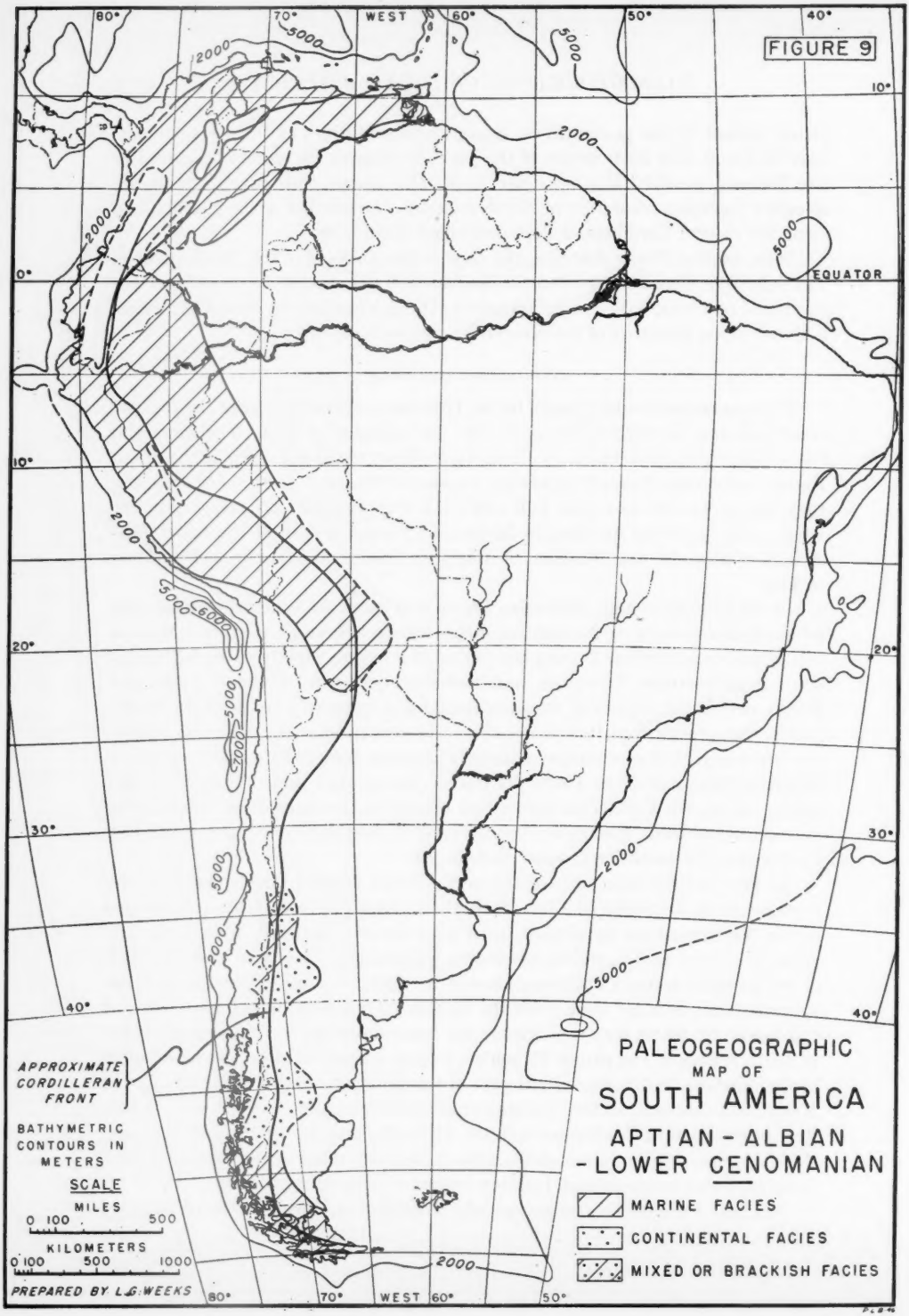
FIGURE 9
80°
70°
WEST
60°
50°
40°
10°
0°
10°
20°
30°
40°
EQUATOR
2000
5000
6000
7000
APPROXIMATE CORDILLERAN FRONT
BATHYMETRIC CONTOURS IN METERS
SCALE
MILES
0 100 500
KILOMETERS
0 100 500 1000
PREPARED BY L.G. WEEKS
PALEOGEOGRAPHIC MAP OF
SOUTH AMERICA
APTIAN - ALBIAN - LOWER CENOMANIAN
MARINE FACIES
CONTINENTAL FACIES
MIXED OR BRACKISH FACIES

Pacific, and connected across northern Venezuela and Trinidad. From Trinidad to Peru the faunas of the seaways appear to have their main affiliation or connection with the Tethys faunas of Europe. While on regional and paleontological grounds it appears certain that the Cretaceous seaways extended through northern Colombia there is on the basis of present information some question whether the area covered by the seas across north Colombia was as extensive as is shown on the accompanying four Cretaceous maps.

In the newly developing Bahia embayment of the east coast of Brazil continental or brackish, possibly estuarine sediments of apparent pre-Albian age are included on the Neocomian paleogeographic map, though they may be Aptian in age.

APTIAN-ALBIAN-LOWER CENOMANIAN

The next map pictures the paleogeography of the continent in Aptian-Albian-Lower Cenomanian time, which is approximately equivalent to the Comanche of the Texas Gulf coast. At the southern end of the continent, the seas had largely withdrawn southward of 47° S. Lat., which area from this time onward became a prominent center of subsidence and deposition. Northward in this embayment, and in the Neuquen-Mendoza area farther northward, marine deposition gave way to a more continental facies in this period.

In the Peruvian embayment the Pacific seas spread inland and southward in the Barremian, Aptian, Albian, and Lower Cenomanian, depositing a marine shale, limestone, and sand facies. The Cenomanian, though spreading widely southward in Peru and Bolivia, is not generally of great thickness and is absent in many places, probably as a result of erosion during the mid-Cretaceous withdrawal of the sea, and subsequently. The base of this transgressive series is a prominent beach or near-shore type of sandstone, which appears to transgress time as the sea advanced, somewhat as does the Nubian sand facies of similar age in the eastern Mediterranean, or as does the basal Comanche sand of the United States.

In the Colombia-Venezuelan seaway a similar marine transgression and deposition mark the stages of this period. In the Bahia embayment marine sedimentation appears for the first time in the Albian. This heralds the beginning of a taphrogenic break-down of eastern lands, permitting the sea to reach the present coastal area of the continent for the first time since the mid-Paleozoic seaways crossed the present coastline.

LATE CENOMANIAN-TURONIAN-LOWER SENONIAN

The next paleogeographic map is designed to picture the Upper Cretaceous, from the late Cenomanian and Turonian through the lower Senonian. This period is approximately the equivalent of the Gulf series in the southern United States and of the Benton-Niobrara-Pierre of the Rocky Mountain front.

In the southern or Patagonian embayment there was marine deposition south

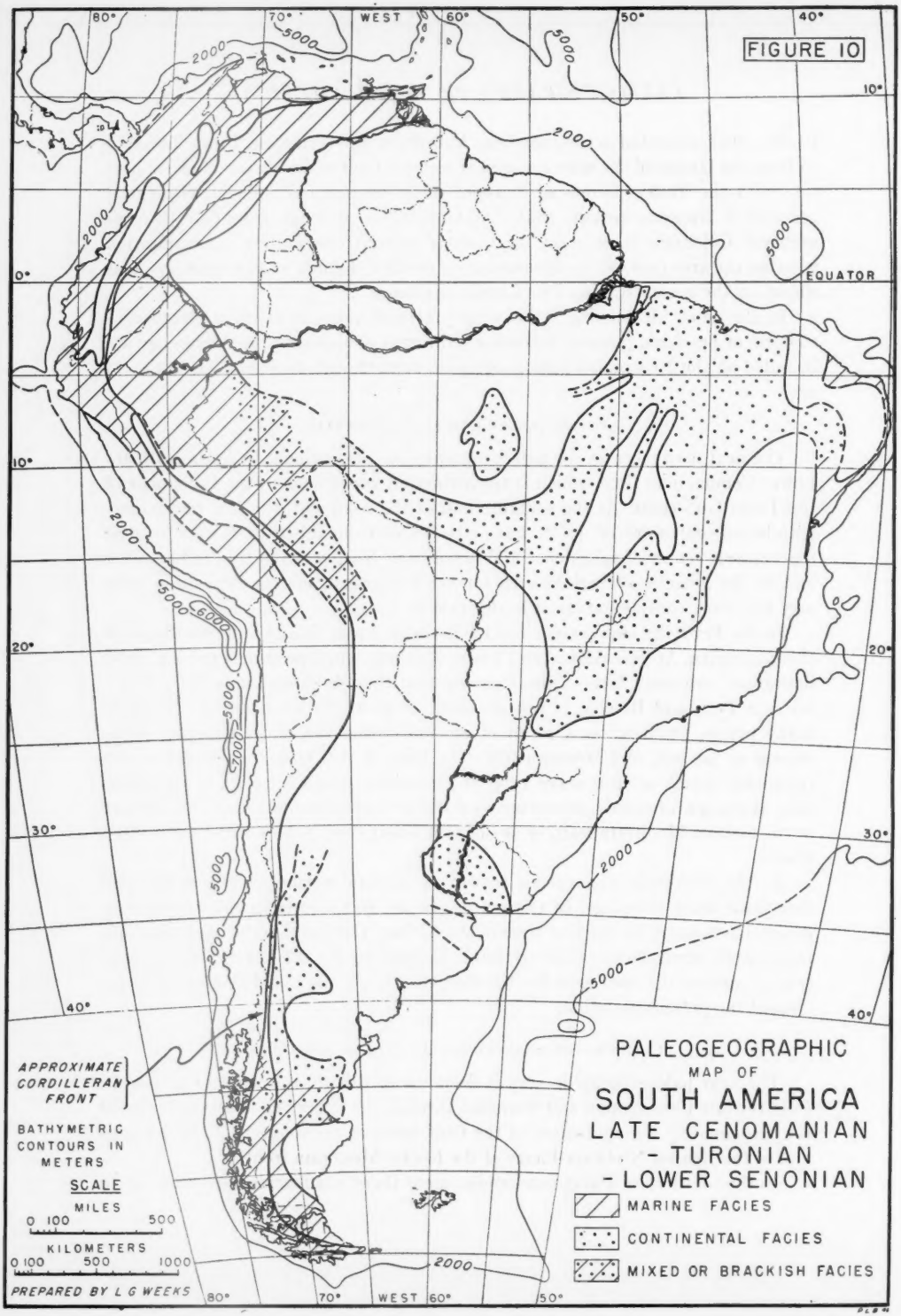
FIGURE 10
80°
70°
WEST
60°
50°
40°
10°
0°
EQUATOR
20°
30°
2000
5000
6000
PALEOGEOGRAPHIC
MAP OF
SOUTH AMERICA
LATE CENOMANIAN
- TURONIAN
- LOWER SENONIAN
MARINE FACIES
CONTINENTAL FACIES
MIXED OR BRACKISH FACIES
APPROXIMATE CORDILLERAN FRONT
BATHYMETRIC CONTOURS IN METERS
SCALE
MILES
0 100 500
KILOMETERS
0 100 500 1000
PREPARED BY L G WEEKS

of about 47° S. Lat., northward from which there was gradation toward, and interfingering of marine with, a brackish and continental facies. The topmost sediments of the series in the continental facies areas contain the bones of large dinosaurs, as did the late Cretaceous swamps of Coahuila and Chihuahua, Mexico, and of Texas and Rocky Mountain basins.

In the Peruvian embayment the sea withdrew during the Cenomanian. Much of the Cenomanian and Turonian appears to be missing over the wide areas of the basin. In the northern part of the geosynclines, in north Peru and Ecuador, the presence of Upper Turonian marine sediments attests the re-invasion of the sea. The sea advanced rapidly through the Upper Turonian and Lower Senonian, spreading very widely in these stages when the bulk of the Upper Cretaceous sequence of marine shales, sandstones, and limestones were deposited.

In the Colombia-Venezuelan seaway there was the same mid-Cretaceous retreat and re-advance of the sea. The Upper Cretaceous transgression, as in Peru, spread more widely over the foreland than did any of the previous seas in this region. The backlands were beginning to rise, pushing the principal geosyncline forward. Embayments in the Bahia and Rio Grande do Norte coastal areas of Brazil also received marine deposits during this period.

As mentioned previously in this review, higher land prevailed in the east and lower lands in the west during most of Paleozoic and Mesozoic history. In Upper Cretaceous time this situation began to reverse itself as the first incipient Andean uplift movements, forerunners of greater movements in the Tertiary, started to change the continental surface to a more level position.

In addition to a much wider overlap of the forelands by the seas, there developed, as a result of the levelling process, extensive interior fresh-water lakes, in which clastic sediments, but including also some locally occurring calcareous beds, were deposited. Principal of these Upper Cretaceous fresh-water deposits include the Cayua and Bauru facies of Upper Cretaceous deposits and other similar sediments widespread over central Brazil. In Patagonia, also, the levelling process is reflected in the far eastward spread of the semi-continental deposits, which contain the dinosaur remains in their highest beds. Similar dinosaur-bearing beds occur in southwest Uruguay and adjacent Entre Rios.

LATE SENONIAN-PALEOCENE

The final paleogeographic map of the Cretaceous represents the period of the late Senonian through the Danian-Paleocene. At the close of the Lower Senonian there was a rather general sea retreat in most areas. In places, such as close to the axes of deformation along mobile belts, the deformation was severe; but over wide areas the unconformity is not as noticeable or important as that of the main Laramide deformation immediately following the Paleocene. The records show that there was another marine advance and retreat in the late Senonian-to-Paleocene interval on the continent, as seen in Patagonia and in northwestern South America. With this general statement we briefly describe the new embayments and seaways.

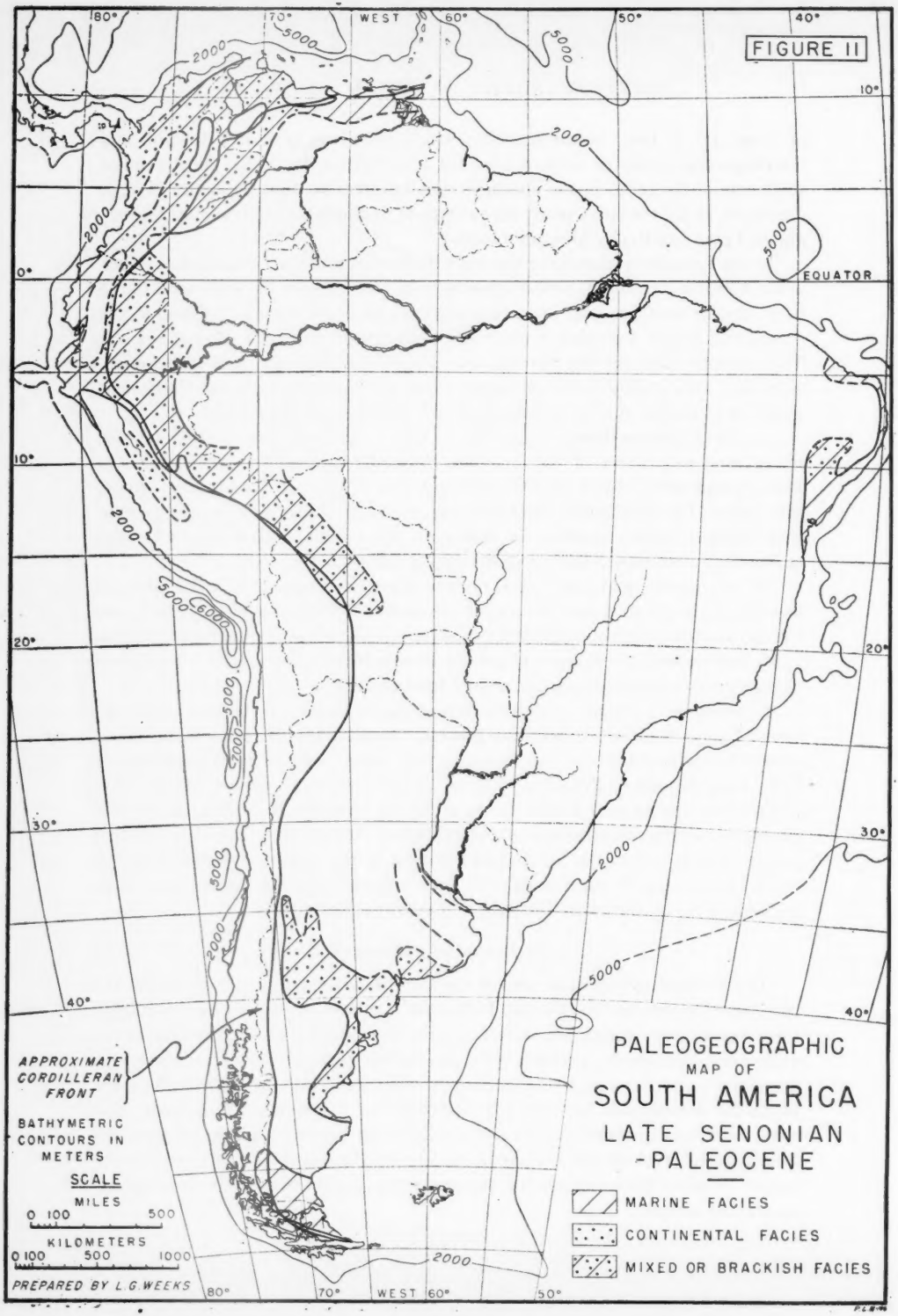
FIGURE II
PALEOGEOGRAPHIC
MAP OF
SOUTH AMERICA
LATE SENONIAN
-PALEOCENE
MARINE FACIES
CONTINENTAL FACIES
MIXED OR BRACKISH FACIES
APPROXIMATE CORDILLERAN FRONT
BATHYMETRIC CONTOURS IN METERS
SCALE
MILES
0 100 500
KILOMETERS
0 100 500 1000
PREPARED BY L.G.WEEKS
EQUATOR
WEST
80°
70°
60°
50°
40°
10°
0°
10°
20°
30°
40°
2000
5000
6000

In the Magallanes area of southern Argentina and Chile marine clastic deposition continued during much of the period. Farther northward in Patagonia, in the Comodora Rivadavia or San Jorge embayment and in the long northwest-trending Rio Negro embayment, marine, brackish and continental beds of late Senonian-to-Paleocene age disconformably overlap Lower Senonian in embayments from the Atlantic. In addition to the disconformity at the base, at least one other occurs within the series itself in these embayments.

Under the city of Buenos Aires basement rocks have been found at about 300 meters depth. Between it and the Sierra Tandil about 250 kilometers south lies the axis of a Miocene embayment. Beneath this we have suggested the possibility of existence of a late Cretaceous embayment.

Farther north on the Atlantic coast marine deposition occurred in the Bahia and Rio Grande do Norte embayments and in a very narrow belt along other parts of the coast.

In the Peruvian embayment the sea withdrew at the end of the prominent Senonian deposition. In the succeeding basin, which was somewhat more restricted in width by the now considerably emerged Andean belt on the southwest and by emergence of the foreland on the east, there was deposited a series of reddish to gray-colored sediments largely brackish to continental in facies but embracing certain marine intercalations. The sediments vary in facies and thickness along the trough of the embayment. From the limited fauna and from stratigraphic considerations, these sediments appear to range in age from late Senonian to earliest Tertiary or Paleocene.

The remnants of a trough within the Andean belt of Peru contain thick continental beds (such as the Rimac series) which have been considered to be late Cretaceous in age, but which are more likely wholly or largely Tertiary.

Along the Pacific coast of Peru and Ecuador occur latest Cretaceous-Paleocene sediments of entirely marine facies. South of Valparaiso on the western coast of Chile there is a narrow coastal overlap of marine sediments reported to be late Senonian in age.

In the Colombia-Venezuela geosynclinal belt the late Cretaceous-early Tertiary time interval varies laterally in the extent to which it is represented by sediments. In places beds as young as middle to upper Eocene or younger rest on strata as old as Lower Senonian or older. In other, deeper basin areas this interval is partly to largely filled in with corresponding shales and sands bearing late Cretaceous to Paleocene marine faunas. An overlap of this period occurs along the western part of the north Panama coast.

Throughout the western hemisphere, and indeed in most parts of the world where Paleocene sediments occur, these sediments in their facies and general affiliations appear more akin to the Cretaceous than to the Tertiary proper, whose first sediments commonly follow in middle Eocene time, or even later.

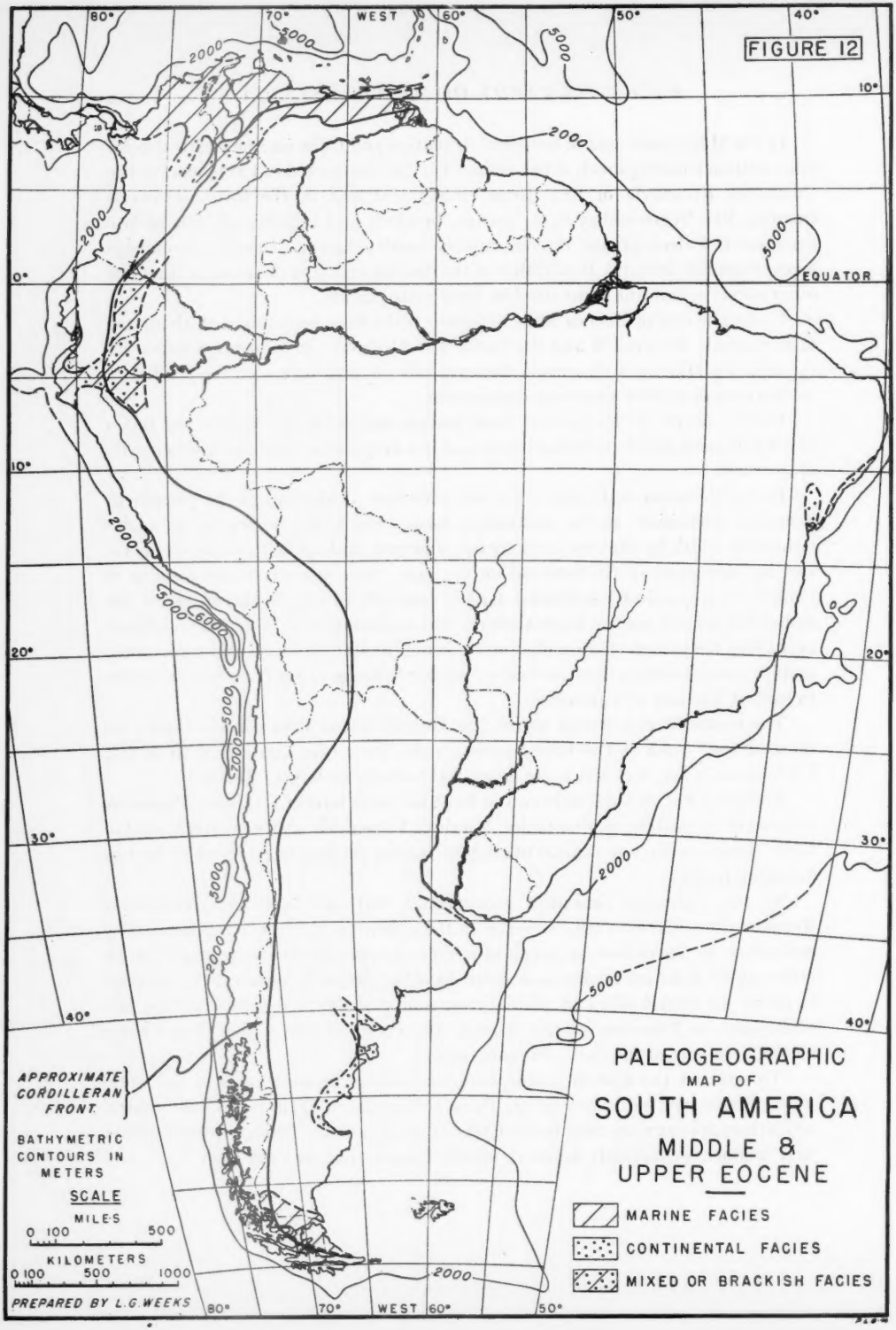
FIGURE 12
80°
70°
WEST
60°
50°
40°
10°
0°
10°
20°
30°
40°
2000
5000
EQUATOR
APPROXIMATE CORDILLERAN FRONT
BATHYMETRIC CONTOURS IN METERS
SCALE
MILES
0 100 500
KILOMETERS
0 100 500 1000
PREPARED BY L.G. WEEKS
PALEOGEOGRAPHIC MAP OF
SOUTH AMERICA
MIDDLE & UPPER EOCENE
MARINE FACIES
CONTINENTAL FACIES
MIXED OR BRACKISH FACIES

EOCENE

While early orogenic movements initiating the uplift of the Andean belt occurred within the Cretaceous, the first major Andean movement of the Tertiary period followed the Danian-Paleocene stage and had its climax in the early Eocene. This corresponds with the main so-called Laramide movement in the North American part of the Cordillera, and to diastrophisms at the same time in other parts of the world.

Except in the deeper basin parts, lower Eocene sediments are not prominently developed in most areas. The sea advanced again following the first Andean movement and, though interrupted by relatively less important disturbances and deposition hiatuses, the middle and upper Eocene witnessed the widest advances of the sea and received the bulk of the sediments of the Eocene epoch within the present limits of the continent.

In the southern Patagonian or Magallanes embayment the Eocene appears to be represented by a clastic, largely marine facies. In the Comodora Rivadavia or San Jorge embayment a continental facies bearing an Eocene land fauna is represented. Sediments of the same age are reported in the Rio Negro embayment and, though unconfirmed, they may also be present in the Buenos Aires embayment. Eocene sediments have been reported to occur in the largely continental facies of the Tertiary in the Bahia embayment and along the coastline of Alagoas and Sergipe on the north.

Eocene sediments occur in a thick clastic marine sequence in the coastal embayments of northwest Peru and in southwestern and western Ecuador. A number of disconformable hiatuses are present in these largely middle and upper Eocene deposits. While Eocene sediments have not been definitely identified east of the Andes it seems likely that they may occur there in a brackish to continental facies which had westward connections with the coastal areas.

Eocene, mainly middle and upper, is well represented by a thick series of marine clastic sediments through the basins of northern Venezuela and Colombia, with southward embayments of a less marine character. Sediments of similar age occur in Panama.

OLIGOCENE-EARLY MIOCENE

What may be termed the second main Andean movement had its climax in early Oligocene time. This disturbance is commonly marked by a withdrawal of the sea starting in late Eocene or early Oligocene and, in many places in northwestern South America, by moderate to severe deformation followed by an overlap of middle to upper Oligocene.

A well defined marine transgression of middle-to-late Oligocene time occurred in the Patagonian embayments. Transgression began somewhat earlier toward the south and sedimentation reached somewhat greater thicknesses successively from north to south in the several embayments shown on the map. There has been

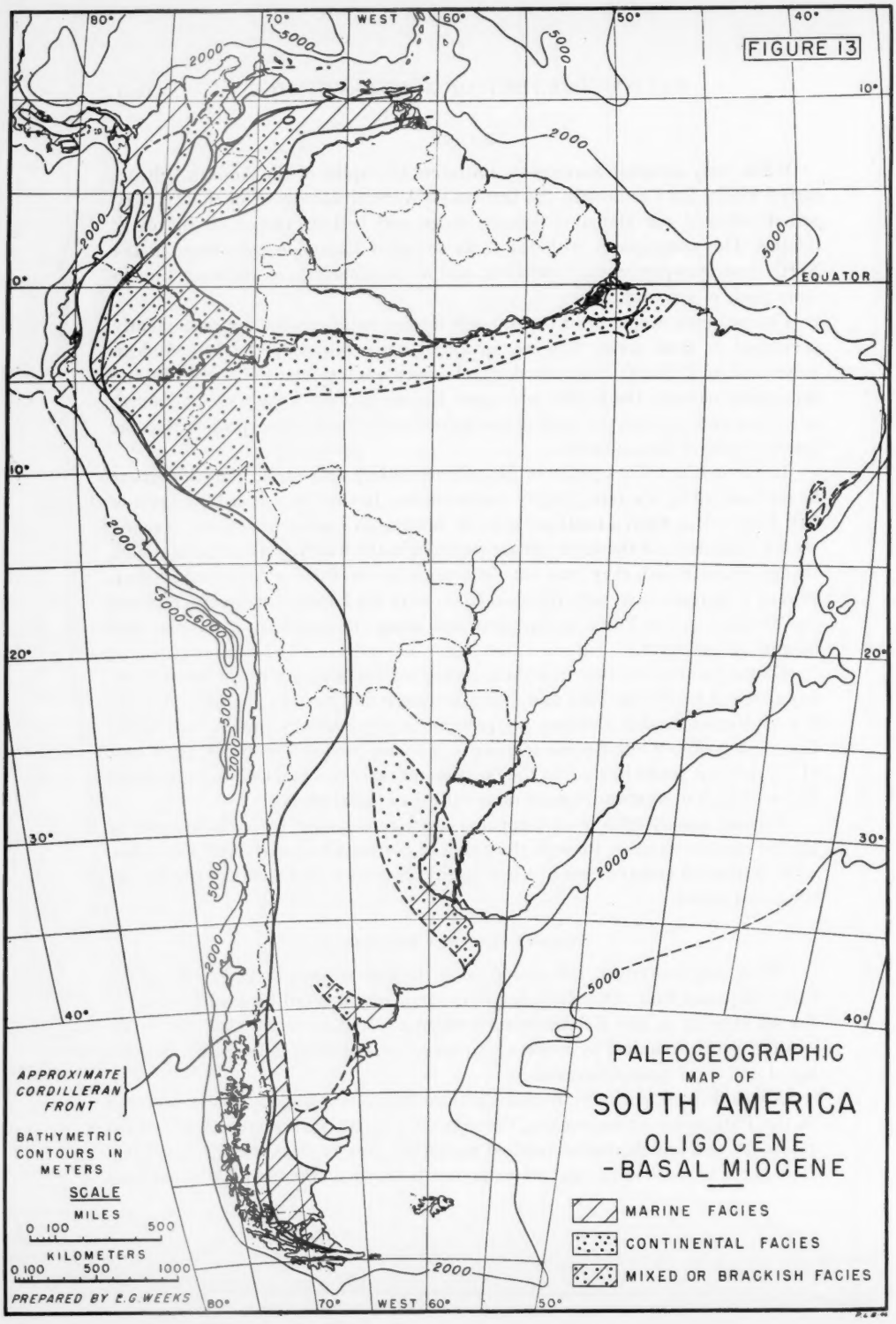
FIGURE 13
80°
70°
WEST
60°
50°
40°
10°
0°
10°
20°
30°
40°
EQUATOR
2000
5000
6000
APPROXIMATE CORDILLERAN FRONT
BATHYMETRIC CONTOURS IN METERS
SCALE
MILES
0 100 500
KILOMETERS
0 100 500 1000
PREPARED BY E.G. WEEKS
PALEOGEOGRAPHIC MAP OF
SOUTH AMERICA
OLIGOCENE - BASAL MIOCENE
MARINE FACIES
CONTINENTAL FACIES
MIXED OR BRACKISH FACIES

some difference of opinion among paleontologists concerning the position of the boundary between the Oligocene and the Miocene in many parts of the world. In general, in South America Oligocene marine sedimentation continued into or through the lower Miocene, though there is some marginal or headward and also upward gradation into brackish and continental deposits.

Little seems to be known of the extent to which transgression and deposition of the upper Oligocene-lower Miocene period occurred in the Buenos Aires or La Plata embayment. There are indications that the maximum transgression in this embayment was somewhat later in the Miocene (see middle Miocene map). Likewise, in the Bahia embayment the age of the largely non-marine Tertiary sediments is still uncertain.

On the west coast of Chile sediments of this period appear to be represented in the small Arauco embayment. Marine overlaps of this period are well represented in the coastal embayments of western and northwestern Peru and of Ecuador.

In Venezuela and Colombia a prominent Oligocene-lower Miocene sea transgressed from the northeast and north more or less widely across Eocene and older rocks. East of the Andes this transgression extended as a semi-marine to brackish and continental facies into Ecuador and Peru, though the existence of archipelagic conditions at the time along the Andean belt would have permitted connections with the Pacific. Eastward, along the middle and lower Amazon trough, all of the Tertiary deposition appears to be continental in character.

MIDDLE MIOCENE

The transgression of seas which followed the second major Tertiary orogenic-epeirogenic movement of early Oligocene age and which spread through the upper Oligocene and early Miocene, continued, with minor interruptions marked by lesser hiatuses, through the middle Miocene. Clastic deposition, derived mainly from the rising Andean belt, was widespread. Sedimentation was so relatively rapid in the middle Miocene basins and embayments that there developed a general retreat of marine and brackish conditions from the positions attained by the sea advances during the Oligocene and early Miocene.

The relative extent of this largely continental deposition and the changing conditions may be visualized by comparing the middle Miocene map with that for the upper Oligocene-early Miocene. Some of the interior continental deposits shown on the middle Miocene map may be in part equivalent in age to earlier Miocene.

The extent of the La Plata marine embayment northward and northwestward is as yet incompletely determined. In the Oran basin of Jujuy and central Salta in northern Argentina the local very high salinity of formation waters indicates a temporary isolation of this area.

Continental deposition continued throughout the pre-Andean and Amazon

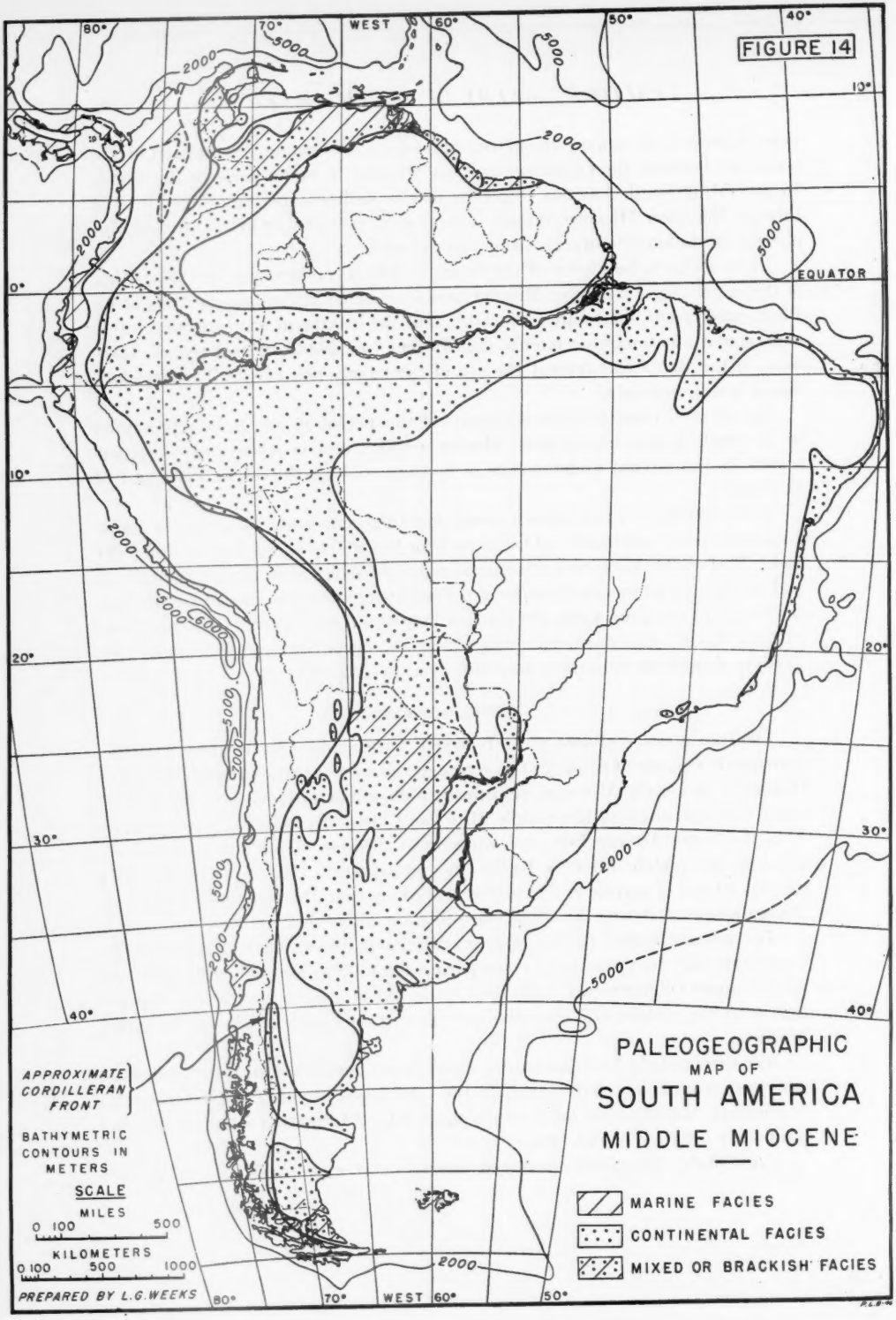
FIGURE 14
80°
70°
WEST
60°
50°
40°
10°
0°
10°
20°
30°
40°
2000
5000
6000
EQUATOR
PALEOGEOGRAPHIC
MAP OF
SOUTH AMERICA
MIDDLE MIOCENE
MARINE FACIES
CONTINENTAL FACIES
MIXED OR BRACKISH FACIES
APPROXIMATE CORDILLERAN FRONT
BATHYMETRIC CONTOURS IN METERS
SCALE
MILES
0 100 500
KILOMETERS
0 100 500 1000
PREPARED BY L.G. WEEKS

troughs, while in the embayments of the Pacific coast, conditions remained prevailingly marine. With the increasing rates of deposition there was also in Venezuela and Colombia a rather general recession of marine facies toward the deeper outer areas of the embayments.

UPPER MIOCENE

The increased rate of clastic deposition in the middle Miocene brought about a filling of the basins, preliminary to the third major Andean orogenic and epeirogenic uplift which had its climax in the upper or late Miocene. The upper Miocene map shows the approximate conditions of upper Miocene time immediately preceding this main movement, which in general corresponds with the so-called Attic diastrophism of Europe.

PLIOCENE

Marine deposition of Pliocene times is rather well developed in many basins of Europe and the Mediterranean regions and in other areas of the eastern hemisphere, as well as in the basins along the western coast of North America. In south America, Pliocene marine deposition is restricted to the outer parts of certain embayments, though continental deposition continued in the old geosynclines of the interior throughout Pliocene and much of Pleistocene time. The largely continental sedimentation was brought to a close in all except limited localities by the fourth major Andean orogenic and epeirogenic diastrophism which had its climax in early Pleistocene time when the seas of the earth withdrew outside the present continental shelves along many or most of the coastlines.

A well defined Pliocene marine embayment was present in southern Patagonia, and limited marine deposition of this period occurred in the La Plata embayment. On the northern and western coasts of the continent marine deposition was of very limited extent during the Pliocene.

Glaciers developed in Pleistocene time in the southern section of the Cordilleras, and the effects of this period of glaciation are general over the southern half of Patagonia.

Beginning in the Mesozoic and continuing throughout the Tertiary, but most particularly in late Tertiary and Quaternary time, there is much evidence of taphrogenic breakdown and marked subsidence of the Pacific and Atlantic border belts, as well as in the Caribbean-Gulf of Mexico areas. Along the whole length of the Andes and in the Mexican, Central American, and Antillean regions, as well as in western North America, considerable volcanic activity and extravasation of lavas accompanied the mountain uplift and the down-faulting and subsidence of border areas beneath the seas.

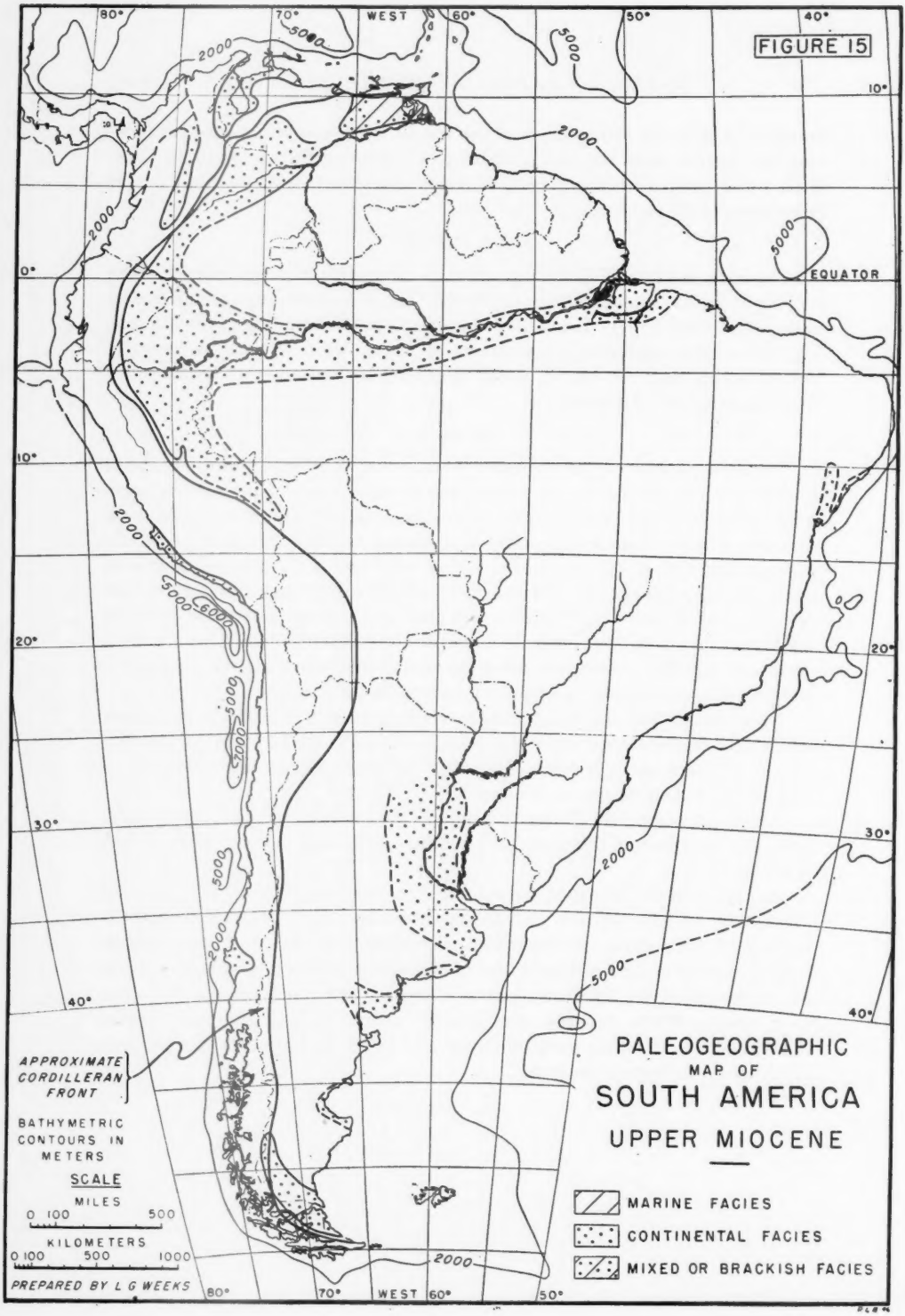
FIGURE 15
80°
70°
WEST
60°
50°
40°
10°
0°
10°
20°
30°
40°
2000
5000
6000
EQUATOR
APPROXIMATE CORDILLERAN FRONT
BATHYMETRIC CONTOURS IN METERS
SCALE
MILES
0 100 500
KILOMETERS
0 100 500 1000
PREPARED BY L G WEEKS
PALEOGEOGRAPHIC MAP OF
SOUTH AMERICA
UPPER MIOCENE
MARINE FACIES
CONTINENTAL FACIES
MIXED OR BRACKISH FACIES

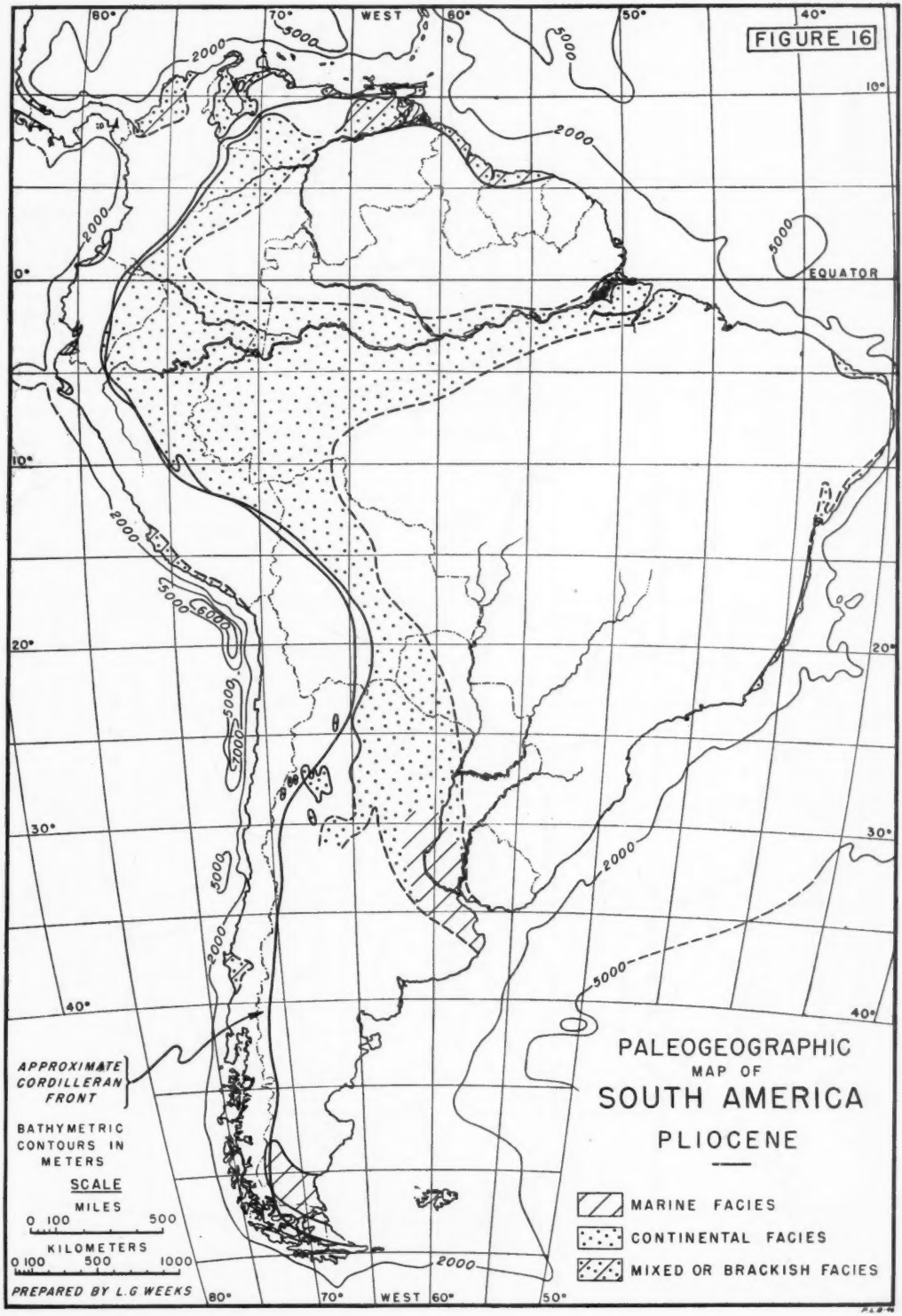
FIGURE 16
80°
70°
WEST
60°
50°
40°
10°
0°
10°
20°
30°
40°
2000
3000
5000
6000
7000
EQUATOR
APPROXIMATE CORDILLERAN FRONT
BATHYMETRIC CONTOURS IN METERS
SCALE
MILES
0 100 500
KILOMETERS
0 100 500 1000
PREPARED BY L.G WEEKS
PALEOGEOGRAPHIC MAP OF
SOUTH AMERICA
PLIOCENE
MARINE FACIES
CONTINENTAL FACIES
MIXED OR BRACKISH FACIES

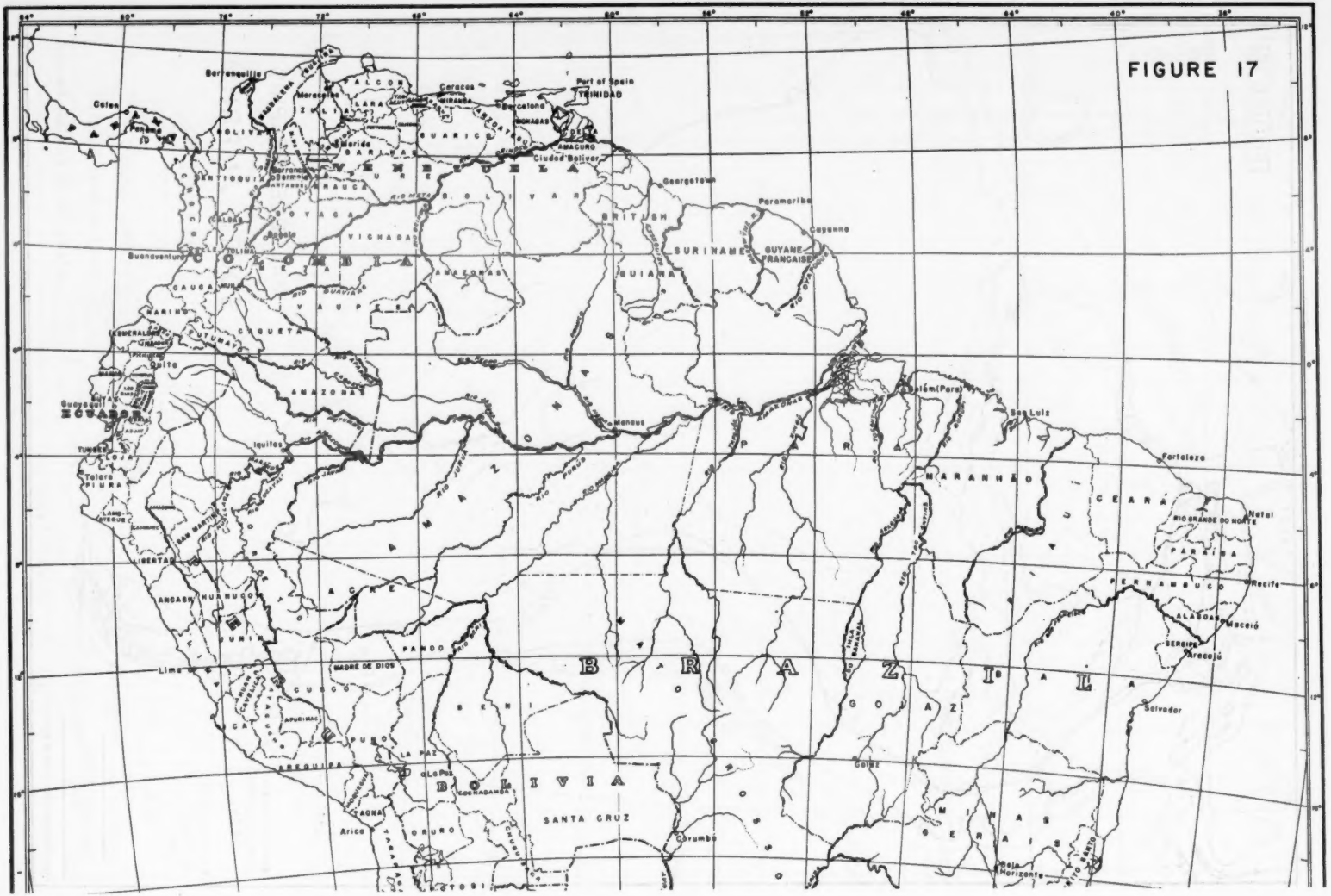
FIGURE 17
Barranquilla
Cartagena
Caracas
Port of Spain
TRINIDAD
Barcelona
Maracaibo
Mérida
Ciudad Bolivar
VENEZUELA
Georgetown
Paramaribo
Cayenne
BRITISH GUIANA
SURINAME
GUYANE FRANCAISE
COLOMBIA
Buenaventura
Popayán
Quito
ECUADOR
Guayaquil
Manaus
Belém (Para)
São Luiz
Fortaleza
Natal
Recife
Maceió
Aracajú
Salvador
Iquitos
Talara
Piura
Lima
Cuzco
Arequipa
La Paz
Oruro
Arica
Cobija
Corumbá
Santa Cruz
BOLIVIA
BRAZIL
Goiaz
Minas Geraes
Bela Horizonte
Rio Santo
AMAZONAS
PARA
MARANHÃO
CEARÁ
RIO GRANDE DO NORTE
PARAHYBA
PERNAMBUCO
ALAGOAS
SERGIPE
ACRE
PANDO
BENI
MADRE DE DIOS
PUNO
APURIMAC
CAJAMARCA
AMAZONAS
LORETO
SAN MARTIN
HUANUCO
ANCASH
LIBERTAD
LAMBAYEQUE
TUMBES
EL ORO
LOJA
ESMERALDAS
MANABI
LOS RIOS
GUAYAS
CHIMBORAZO
TUNGURAHUA
COTOPAXI
PICHINCHA
IMBABURA
CARCHI
NARIÑO
CAUCA
HUILA
TOLIMA
VALLE
CHOCO
RISARALDA
CALDAS
QUINDIO
ANTIOQUIA
CORDOBA
SUCRE
BOLIVAR
CESAR
MAGDALENA
ATLANTICO
GUAJIRA
NORTE DE SANTANDER
SANTANDER
BOYACA
CUNDINAMARCA
TOLIMA
META
VICHADA
GUAINIA
VAUPES
CAQUETA
PUTUMAYO
ARAUCA
CASANARE
GUARICO
ANZOATEGUI
MONAGAS
AMACURO
DELTA
SUCRE
NUEVA ESPARTA
FALCON
LARA
ZULIA
TACHIRA
BARINAS
PORTUGUESA
YARACUY
CARABOBO
APURE
Rio Negro
Rio Solimões
Rio Madeira
Rio Purus
Rio Juruá
Rio Tapajoz
Rio Xingu
Rio Tocantins
Rio Araguaya
Rio São Francisco
Rio Paraguay
Rio Guaporé
Rio Mamoré
Rio Beni
Rio Orinoco
Rio Meta
Rio Guaviare
Rio Inirida
Rio Negro
Rio Branco
Rio Caroni
Rio Paragua
Rio Cuyuni
Rio Mazaruni
Rio Essequibo
Rio Corentyne
Rio Suriname
Rio Maroni
Rio Oyapock
Rio Cauca
Rio Magdalena
Rio Sinu
Rio Atrato
Rio Zulia
Rio Catatumbo
Rio Arauca
Rio Meta
Rio Guaviare
Rio Inirida
Rio Vaupes
Rio Caquetá
Rio Putumayo
Rio Napo
Rio Pastaza
Rio Marañon
Rio Ucayali
Rio Huallaga
Rio Pachitea
Rio Urubamba
Rio Apurimac
Rio Mantaro
Rio Pampas
Rio Beni
Rio Madre de Dios
Rio Acre
Rio Purus
Rio Juruá
Rio Javary
Rio Iça
Rio Negro
Rio Solimões
Rio Madeira
Rio Tapajoz
Rio Xingu
Rio Tocantins
Rio Araguaya
Rio São Francisco
Rio Paraguay
Rio Guaporé
Rio Mamoré
Rio Beni
Rio Orinoco
Rio Meta
Rio Guaviare
Rio Inirida
Rio Negro
Rio Branco
Rio Caroni
Rio Paragua
Rio Cuyuni
Rio Mazaruni
Rio Essequibo
Rio Corentyne
Rio Suriname
Rio Maroni
Rio Oyapock
Rio Cauca
Rio Magdalena
Rio Sinu
Rio Atrato
Rio Zulia
Rio Catatumbo
Rio Arauca
Rio Meta
Rio Guaviare
Rio Inirida
Rio Vaupes
Rio Caquetá
Rio Putumayo
Rio Napo
Rio Pastaza
Rio Marañon
Rio Ucayali
Rio Huallaga
Rio Pachitea
Rio Urubamba
Rio Apurimac
Rio Mantaro
Rio Pampas
Rio Beni
Rio Madre de Dios
Rio Acre
Rio Purus
Rio Juruá
Rio Javary
Rio Iça

SOUTH AMERICA
SCALE
50 0 100 200 300 400 500 MILES
100 0 200 400 600 800 1000 KILOMETERS
TARIJA
Antofagasto
Los Andes
Salta
Tucuman
Tucumano
SANTIAGO DEL ESTERO
Santiago del Estero
Asuncion
Corrientes
CORRIENTES
ENTRE RIOS
Rosario
Cordoba
Santa Fe
SAN JUAN
Valparaiso
Santiago
Mendoza
MENDOZA
BUENOS AIRES
Montevideo
URUGUAY
Rio Grande
Porto Alegre
RIO GRANDE DO SUL
SANTA CATARINA
Curitiba
PARANA
SAO PAULO
São Paulo
Santos
RIO DE JANEIRO
Concepcion
NEUQUEN
Neuquén
RIO NEGRO
PAMPA
Bahía Blanca
Comodoro Rivadavia
SANTA CRUZ
FALKLAND ISLANDS
TIERRA DEL FUEGO

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MIDDLE ORDOVICIAN LIMESTONES IN CENTRAL KANSAS[1]

HALL TAYLOR[2]
New York, N. Y.

ABSTRACT

In the subsurface of north-central Kansas, middle Ordovician Viola limestones, named after the Oklahoma surface section, are separable, lithologically, into six member zones, three of which are cherty. Numbered downward, these zones are designated as (1) upper limestone, (2) upper cherty member, (3) middle limestone, (4) middle cherty member, (5) lower limestone, and (6) lower cherty or basal clastic member. The upper limestone is dolomitic, occurs beneath the Maquoketa-Sylvan unconformity, and in different places overlies several older zones. The upper cherty member is calcitic and limited, in central Kansas, to the northern part. The middle and lower limestones, zones 3 and 5 are calcitic in the north, becoming dolomitic toward the south. Lying between them, possibly with disconformity, is the middle cherty member, zone 4, characterized by black-specked dolomite-bearing chert. The lower cherty or basal clastic member, zone 6, includes cherty limestones, sandy in places and probably not everywhere coetaneous, which overlie Simpson shales and sands. Most Viola oil production comes from zones 4 and 5.

The Viola is over 250 feet thick in the north, but thins toward the south. Zone 5 is the most widespread, representing the maximum advance of Viola seas. The overlying members developed in less extensive seaways which advanced from the north. Viola beds are truncated on the flanks of the Central Kansas uplift, but formerly covered at least part of that structure. They are thinner near the Nemaha arch than on the northwest, and are missing locally between the arch and the uplift.

Lithologic comparisons with tentative correlations by Lee in northeastern Kansas indicate zones 1, 2, and 3 may be equivalent to the Stewartville (or younger), zones 4 and 5 to the Prosser, and zone 6 to the lower Prosser or Decorah formations of Iowa.

INTRODUCTION

Scope of paper.—Ordovician strata occur in the subsurface section over much of central Kansas (Figs. 1 and 2). They lie beneath hundreds, even thousands of feet of younger beds ranging in age from Recent to Siluro-Devonian, and form some of the most important oil reservoirs in the state.

On the basis of lithology, petroleum geologists have divided these Ordovician beds into four major units, names for which are borrowed from outcrops of approximately equivalent sections in neighboring states. At the top is a shale of upper Ordovician age, called both Maquoketa and Sylvan because its stratigraphic position corresponds approximately with that shown by outcrops of those formations, the former in Iowa, the latter in Oklahoma. Lying unconformably beneath this shale is a limestone belonging in the upper middle Ordovician, and originally named Viola because it was believed about equivalent to the Viola beds which crop out farther south in the Arbuckle Mountains of Oklahoma.

[1] Manuscript received, September 12, 1946.

[2] Instructor in geology, Columbia University, New York 27, N. Y. Research for this paper, supported by a William Bayard Cutting Traveling Fellowship from Columbia University, began in the summer of 1940 and continued until October, 1941, when it was interrupted by the war. The work was completed following cessation of hostilities and the writer's release from active duty. During progress of the study Professor Marshall Kay of Columbia University gave generously of his time to the problems which arose. Professor R. C. Moore, director of the Kansas Geological Survey, provided survey equipment and well samples. Robert Carmody of the Gulf Oil Corporation critically read the manuscript and offered many helpful suggestions. To these persons and to all others whose efforts have made this paper possible the writer extends sincere thanks.

Below this limestone there is a succession of lensing shales and sands, some of them dolomitic, of lower middle Ordovician age, collectively called the Simpson formation after similar strata in Oklahoma. The fourth and lowest subdivision belongs in the lower Ordovician, and is the Arbuckle "dolomite," a name also borrowed from Oklahoma stratigraphy.

This paper describes the stratigraphy, structure, and paleogeographic history of the limestone section beneath the Maquoketa-Sylvan shales and above the Simpson formation in central Kansas. In Oklahoma this section was originally named the Viola limestone by Taff.[3] Subsequently two members, the Fernvale at the top and the Bromide at the base, were separated and given formational rank distinct from the original Viola. No such separation has been attempted by geologists working in central Kansas, and the entire limestone section is called Viola though exact correlations with Oklahoma outcrops have not been carried across the intervening subsurface areas. The Kansas strata are approximately equivalent not only to the Viola of Oklahoma, but also to the Kimmswick limestone in eastern Missouri, the Galena limestone in Iowa, and the Fremont limestone in Colorado, all of which belong in the middle Ordovician Mohawkian series, and are principally of Trenton age. In this paper the name Viola limestone is retained because of its favor among petroleum geologists, even though the strata are not exact equivalents of the Oklahoma Viola beds.

Lee[4] has carried Kimmswick correlations from Missouri into northeastern Kansas. The present paper extends Viola correlations across central Kansas, and connects on the northeast with wells described by Lee in Pottawatomie, Wabaunsee, and Riley counties.

Samples from more than 200 holes were studied during preparation of this paper, and residues were utilized from many of the wells. Also several hundred driller's logs were examined. In compiling data, the depth measurements written on samples were used, and lag or similar corrections were not applied since they are normally variable but small, are impossible to determine accurately and do not affect the overall stratigraphic picture presented in a region.

Subsurface structures.—Encompassed in this study are about 10,000 square miles lying between two structural highs—the Nemaha granite ridge or arch on the east and the Central Kansas uplift on the west (Fig. 1, inset).

The Nemaha Mountains were originally named by Moore,[5] and form a northeast-southwest trending ridge in the pre-Cambrian basement rocks. The arch rose principally in late Mississippian and early Pennsylvanian time.

The Central Kansas uplift, named by Morgan[6] and later more fully described

[3] J. A. Taff, "Description of the Atoka Quadrangle," *U. S. Geol. Survey Folio 79* (1902), pp. 1–8.

[4] Wallace Lee, "Stratigraphy and Structural Development of the Forest City Basin in Kansas," *Kansas Geol. Survey Bull. 51* (1943), pp. 35–40, 60 and 61.

[5] R. C. Moore, "Geologic History of the Crystalline Rocks of Kansas," *Bull. Amer. Assoc. Petrol. Geol.*, Vol. 2 (1918), p. 112.

[6] L. C. Morgan, "Central Kansas Uplift," *Bull. Amer. Assoc. Petrol. Geol.*, Vol. 16, No. 5 (May, 1932), p. 483.

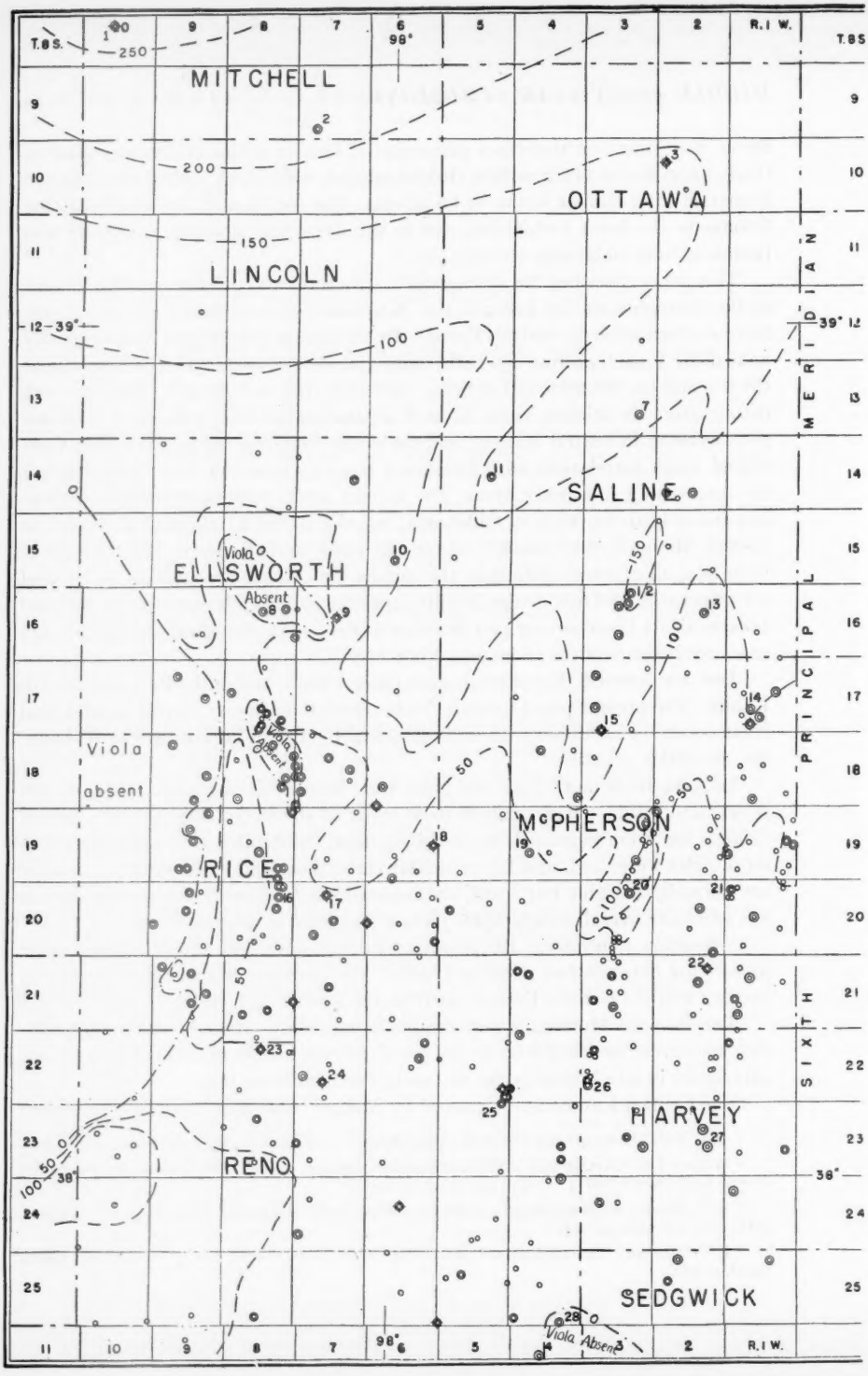
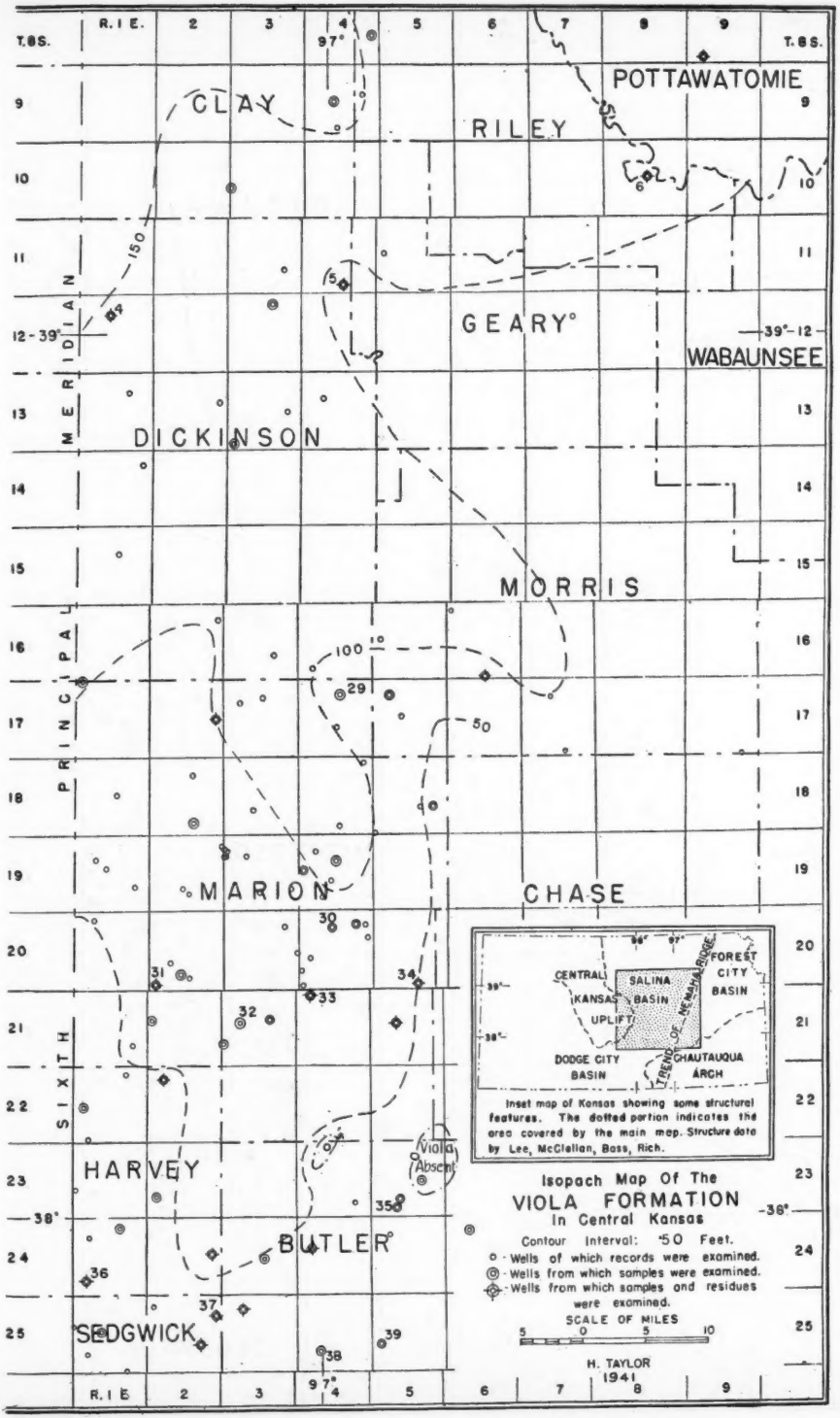


FIG. 1.—Isopach map of Viola formation in central Kansas. Figures beside certain



wells refer to correspondingly numbered wells in cross sections *AA'* to *HH'*.

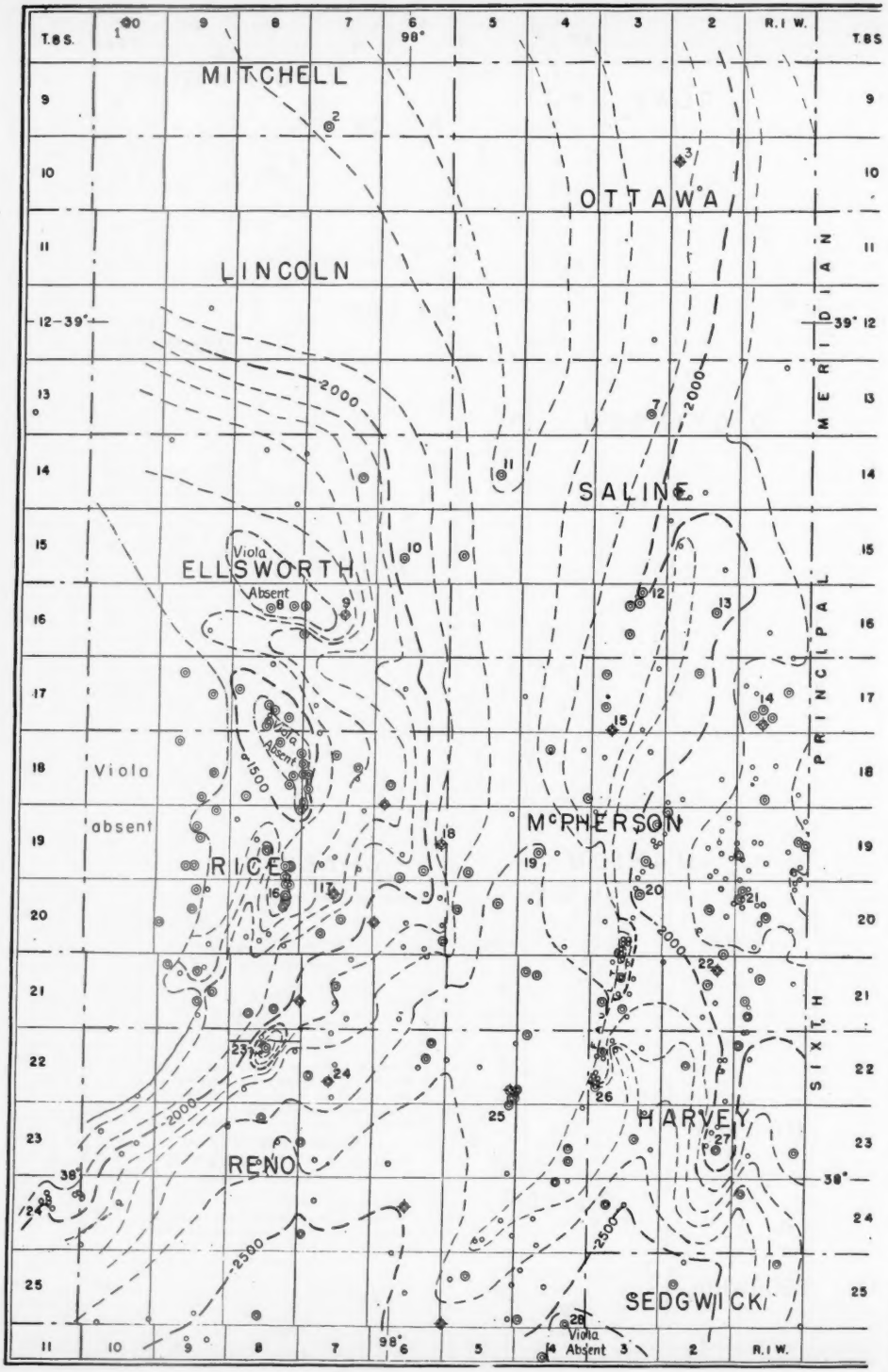
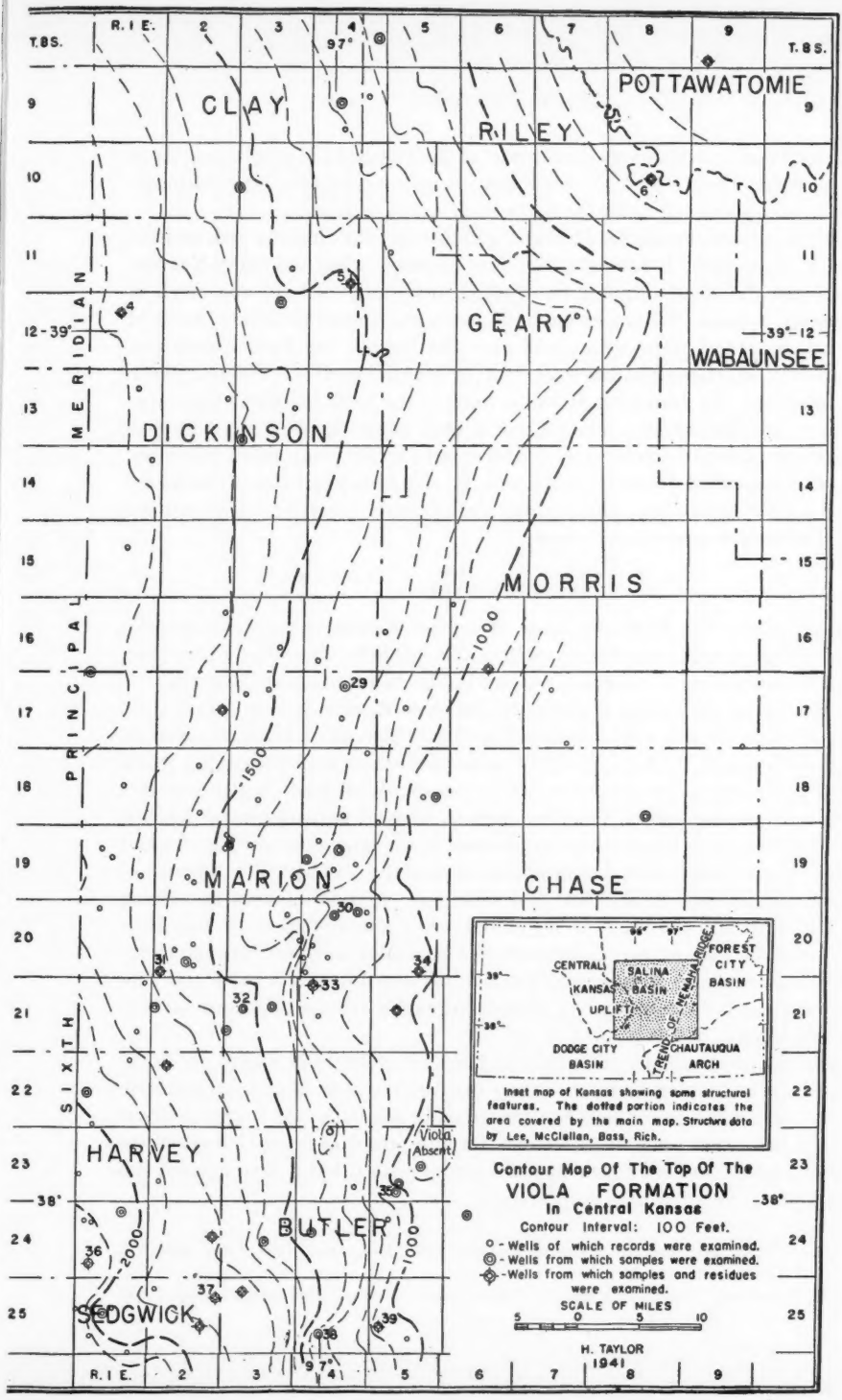


FIG. 2.—Contour map of top of Viola formation in central Kansas. Zero datum plane is mean sea-level.



Figures beside certain wells refer to correspondingly numbered wells in cross sections *AA'* to *HH'*.

by Koester,[7] was a positive area during part of the Paleozoic. It was largely if not entirely covered by Ordovician seas, but thereafter probably was partially emergent until permanently buried by Pennsylvanian sediments.

The Salina basin, named by Barwick,[8] lies between the Nemaha arch and the Central Kansas uplift. It formed in the late Paleozoic when the rising Nemaha arch bisected the North Kansas basin which previously had covered much of northeastern Kansas. Within or near the basin are several anticlines, some of which are structural traps for oil and gas. The largest, the Voshell anticline, crosses central McPherson and western Harvey counties northeast and southwest.

Terminology.—In describing dolomitic parts of the Viola limestone this paper uses the word *dolomite* as a mineral, not a rock name. Rocks containing predominant amounts of dolomite crystals and rhombs are by many called dolomites. Herein they are called dolomitic limestones. If calcite predominates the rocks are termed calcitic limestones. Thus *calcite* and *dolomite* are reserved as *mineral* names; *limestone* is used as a *rock* name.

GENERAL SURVEY

Stratigraphy.—The Viola limestone of central Kansas is separable, on the basis of lithology, into six cherty, calcitic and dolomitic limestone zones (Fig. 3), with a total thickness exceeding 250 feet in Mitchell County at the north.

At the top of the section is the *upper limestone member* or *zone 1*. It is thin, commonly under 20 feet, and is distinguished by an abundance of coarse dolomite rhombs and crystals. In north-central Kansas its contact with underlying strata is sharp and distinct, but farther south is less clearly defined. Apparently this zone directly overlies several Viola members in different parts of central Kansas, but its delimitation is based solely on presence of the large dolomite rhombs and crystals, criteria which must be considered of doubtful validity. The thinness of the zone, and its wide areal extent and superposition upon different underlying zones with which, in the south, it has gradational contacts, indicate it may be in part a zone of dolomitization beneath the Maquoketa-Sylvan unconformity rather than a separate stratigraphic member deposited during a particular substage of time. A full understanding of its stratigraphic relationships awaits study of the region north of this report.

The exact areal extent of this zone may not be as shown in Figure 12. In the north, where underlying beds are largely calcitic, the zone is easily recognized. Farther south, where lower beds become partially dolomitic, the coarse dolomite rhombs at the top of some Viola sections are interpreted as facies changes in the underlying zones, and are not mapped as part of zone 1, but it is recognized this practice may have introduced inaccuracies.

[7] Edward A. Koester, "Geology of Central Kansas Uplift," *Bull. Amer. Assoc. Petrol. Geol.*, Vol. 19, No. 10 (October, 1935), pp. 1405–26.

[8] John S. Barwick, "The Salina Basin of North-Central Kansas," *Bull. Amer. Assoc. Petrol. Geol.*, Vol. 12, No. 2 (February, 1928), p. 170.

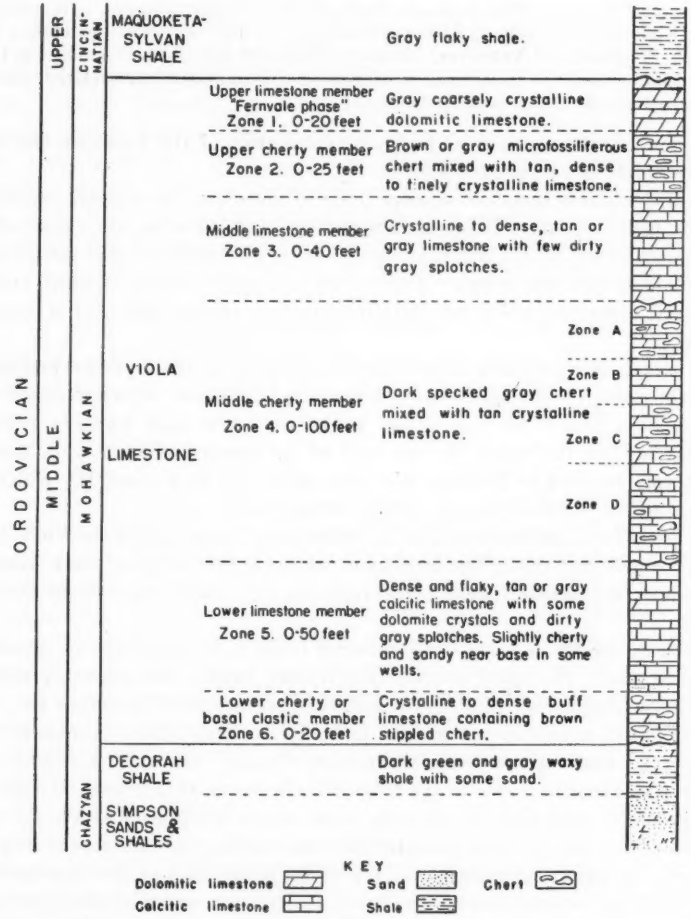

ORDOVICIAN
UPPER
MIDDLE
CINCINNATIAN
MOHAWKIAN
CHAZYAN
MAQUOKETA-SYLVAN SHALE
Gray flaky shale.
Upper limestone member "Fernvale phase" Zone 1. 0-20 feet
Gray coarsely crystalline dolomitic limestone.
Upper cherty member Zone 2. 0-25 feet
Brown or gray microfossiliferous chert mixed with tan, dense to finely crystalline limestone.
Middle limestone member Zone 3. 0-40 feet
Crystalline to dense, tan or gray limestone with few dirty gray splotches.
Zone A
Zone B
VIOLA
Middle cherty member Zone 4. 0-100 feet
Dark specked gray chert mixed with tan crystalline limestone.
Zone C
LIMESTONE
Zone D
Lower limestone member Zone 5. 0-50 feet
Dense and flaky, tan or gray calcitic limestone with some dolomite crystals and dirty gray splotches. Slightly cherty and sandy near base in some wells.
Lower cherty or basal clastic member Zone 6. 0-20 feet
Crystalline to dense buff limestone containing brown stippled chert.
DECORAH SHALE
Dark green and gray waxy shale with some sand.
SIMPSON SANDS & SHALES
KEY
Dolomitic limestone
Calcitic limestone
Sand
Shale
Chert

FIG. 3.—Generalized geologic column of middle Ordovician limestones in central Kansas, with lithologic descriptions applicable to thick sections in the north. Lateral changes toward the south are described in text.

Some geologists have tentatively correlated this member with the "Fernvale" formation of similar lithology and stratigraphic position in the Oklahoma surface section, referring to it as the "Fernvale phase of the Viola." However, Shideler[9] has shown that the Oklahoma "Fernvale" is unlike the Fernvale of the Nashville basin, and has proposed that the Oklahoma strata be renamed Ada. He writes in part:

[9] W. H. Shideler, "Fernvale Correlations" (abstract), *Proc. Geol. Soc. America for 1936* (1937), pp. 367–68.

> The typical Fernvale of the Nashville Basin and Wilmington, Illinois . . . is correlated with the Elkhorn of the typical Richmond section. . . . The "Fernvale" extending from Glen Park, Missouri, and Valmeyer, Illinois, to the south side of the Arbuckles in Oklahoma . . . [for which] the name Ada is proposed . . . is tentatively correlated with the Maquoketa, but may not even be Richmond.

In view of the uncertainties regarding correlation of the Fernvale the name probably should not be used in Kansas.

The *upper cherty limestone member* (*zone 2*) underlies the coarsely crystalline dolomitic beds of zone 1. It carries large amounts of brown or gray sharp-edged rather smooth chert which is irregularly splotched with white or gray microfossils.

The *middle limestone member* (*zone 3*) is a tan or gray, dense to finely crystalline calcitic limestone which normally contains less than 10 per cent of insoluble material.

The *middle cherty member* (*zone 4*) is differentiated by the dark-specked microfossiliferous rough and smooth chert, dolocastic in residues, which is mixed with tan crystalline limestone that is calcitic in the north and becomes partially dolomitic toward the south. In the area of its greatest thickness in Mitchell County this member is divisible into four zones (A, B, C, and D), which are described in the Mitchell County section of this paper.

The *lower limestone member* (*zone 5*) is the most widespread of the Viola zones, and is brown or gray crystalline limestone, calcitic in the north but more dolomitic in the south. It resembles zone 3, and contains only small amounts of insoluble material.

The *lower cherty* or *basal clastic member* (*zone 6*) is a mixture of limestone, chert, and sand. The chert is microfossiliferous, brown and unevenly colored, presenting a stippled or minutely mottled appearance with numerous tiny dark brown dots in a lighter brown matrix. It occurs in north central Kansas but was not observed south of southern McPherson County. However, a second chert appears in this southern area at the base of Viola strata. It is brown, microfossiliferous, dolomitic and dark-specked. In some pieces it appears as though filled with bits of fine lace; if these microfossiliferous markings are numerous they give the chert a stippled appearance. In a few wells, where both of the aforedescribed cherts occur, this second chert is stratigraphically lower and lies in Simpson sands and shales. But the first described chert occurs in limestones, and belongs in the basal clastic zone. The strata of this basal zone are commonly thin, and are missing in some wells. They represent the first impure clastic deposits of a limestone forming sea as it covered the land. If the term Viola is restricted to the pure limestone part of the section these beds are pre-Viola. They are discussed in this paper because they are chiefly limestones and thus more like Viola strata than underlying Simpson sands and shales.

Beneath this basal clastic member in many wells there is a green or black waxy shale (Fig. 27) of variable thickness, with an appearance which is different from the stratigraphically higher spore bearing Chattanooga shales (Fig. 26) or

the dolomitic and flaky Maquoketa-Sylvan strata. Udden,[10] using fossil determinations by T. E. Savage, was the first to record the Decorah age of this waxy shale, which is underlain by Simpson sandy beds (Fig. 28).

Correlations.—Detailed correlations connecting the central Kansas Ordovician limestone section with outcrops have not been published. However, Lee[11] has traced the Kimmswick limestone from Missouri into northeastern Kansas, recognizing a three-fold division established by McQueen and Greene[12] in northwestern Missouri. Lee extends his correlations westward into Pottawatomie, Wabaunsee, and Riley counties where the three divisions include an upper non-cherty dolomitic limestone, a middle cherty member (which is itself divisible into three units, the middle one of which is non-cherty), and a basal sparsely cherty limestone. These three members form a limestone section which is continuous in the subsurface with the Viola limestone of central Kansas. The middle cherty member of northeastern Kansas is equivalent to the middle cherty limestone (zone 4) of central Kansas as described in this paper. The upper non-cherty member of northeastern Kansas fills the part of the section occupied by the upper limestone, upper cherty and middle limestone members (zones 1, 2,and 3) of north central Kansas, and is believed equivalent to zone 3; and the lower sparsely cherty member of northeastern Kansas is probably equivalent to the lower limestone (zone 5) and possibly the lower cherty or basal clastic beds (zone 6) of central Kansas.

Correlations of the three divisions of the middle cherty member of the Kimmswick of northeastern Kansas with the beds of the same member (zone 4) in central Kansas are uncertain, but it seems likely that the middle and comparatively non-cherty division of the member in northeastern Kansas is equivalent to the relatively non-cherty zone B portion of zone 4 in north-central Kansas. Zone A would then be equivalent to the upper cherty division, and zones C and D to the lower cherty division of the middle cherty member in northeastern Kansas.

Assignment of proper outcrop names to the various members has not yet been accomplished, and may never be practicable if sedimentary conditions during deposition varied so much between outcrop and subsurface areas that corresponding zones do not occur in both places. But some tentative correlations have been advanced by Lee[13] who in discussing the Kimmswick of northeastern Kansas writes:

McQueen and Greene ("Geology of Northwestern Missouri," *Missouri Bur. Geol. and Mines*, Vol. 25, 2d ser., 1938, p. 40) divide the Kimmswick of northwestern Missouri into

[10] Jon A. Udden, "Occurrence of Ordovician Sediments in Western Kansas," *Bull. Amer. Assoc. Petrol. Geol.*, Vol. 10, No. 6 (June, 1926), p. 635.

[11] Wallace Lee, *op. cit.*, pp. 60–61.

[12] H. S. McQueen and F. C. Greene, "Geology of Northwestern Missouri," *Missouri Bur. Geol. and Mines*, Vol. 25, 2d Ser. (1938), pp. 40–42.

[13] Wallace Lee, *op. cit.*, pp. 35, 36, and 37.

three divisions. . . . The middle division is very cherty dolomite. . . . McQueen regards the top of the very cherty member as the top of rocks of Black River age and believes the upper most division to be of probable Trenton age unconformably overlying the cherty Black River.

E. C. Reed, of the Nebraska Geological Survey, and H. G. Hershey, of the Iowa Geological Survey, . . . agree that whatever the age of the rocks referred to the Kimmswick in northwestern Missouri, these are the same rocks that are classified in adjoining parts of Iowa and Nebraska as Prosser limestone, which is of early Trenton age and above the Ian and Guttenberg rocks. . . .

. . . The Kimmswick is definitely unconformable below the Maquoketa shale. It seems possible that the upper or non-cherty zone is of Fernvale age. . . .

. . . If the Prosser age of the cherty beds of the Kimmswick is accepted, this [uppermost or non-cherty] zone probably represents the Stewartville which is reported by Kay ("Ordovician System in the Upper Mississippi Valley," *Kansas Geol. Soc. Guidebook 9th Ann. Field Conference* (1935), p. 295, Fig. 211) to be disconformable above the Prosser.

Should the Prosser age of the middle cherty division in northeastern Kansas be established, it is likely that the members designated as zones 1, 2, and 3 in this paper belong in the Stewartville (or younger) sequence, zones 4 and 5 in the Prosser, and zone 6 in the lower Prosser or Decorah.

Structure.—The thickest and most complete Viola section in central Kansas lies in Mitchell County and adjacent areas (Fig. 1). The beds thin toward the west, south, and east (Figs. 4, 5, 6, 7, 8, 9, 10, and 11), largely through disappearance of the upper zones (Fig. 12). The strata disappear on the flanks of the Central Kansas uplift, and are missing from the top of most of that structure. They are gone locally from highs just east of the uplift in Ellsworth and Rice counties, from parts of the Nemaha arch in Butler County, and from an area in and adjacent to T. 25 S., R. 4 W., in Reno County.

Over most of central Kansas the beds thin in a rather uniform manner. However, in some places, notably the region of the Voshell anticline in central McPherson County (T. 19 and 20 S., R. 3 W.) there is some local thickening of the beds, suggesting that relatively thick middle Ordovician sedimentary deposits accumulated in areas in which late Paleozoic movements created anticlinal structures which are today the sites of very productive oil fields.

Viola beds over much of central Kansas dip gently into a trough the center of which extends north and south through western Ottawa, Saline, and McPherson counties, and southwest across Reno County (Fig. 2). This was named the Conway syncline by Koester.[14] In some places dips are modified, steepened and even reversed by local structural features. The Welch, Bornholdt, and Smyres oil fields in eastern Rice and western McPherson counties lie along the trend of one such terrace-like modification in dip. Faulting is uncommon in the area, but along a fault zone on the west side of the Voshell anticline in McPherson and Harvey counties, beds on the east are several hundred feet higher than those on the west (Figs. 2, 6, and 7).

[14] Edward A. Koester, *op. cit.*, p. 1421.

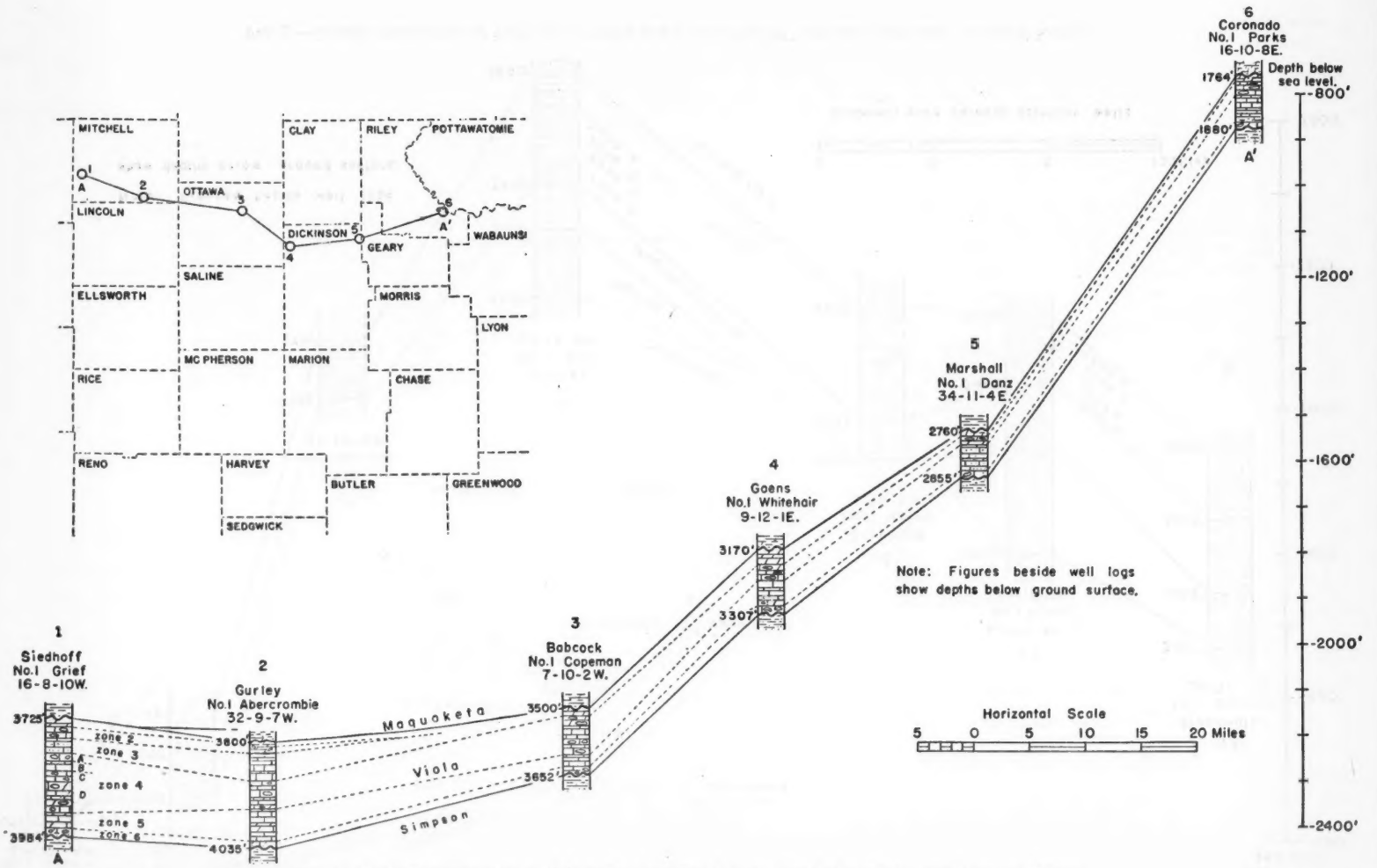


FIG. 4.—Geologic cross section of Viola strata along line AA' (see inset index map) in north-central Kansas.

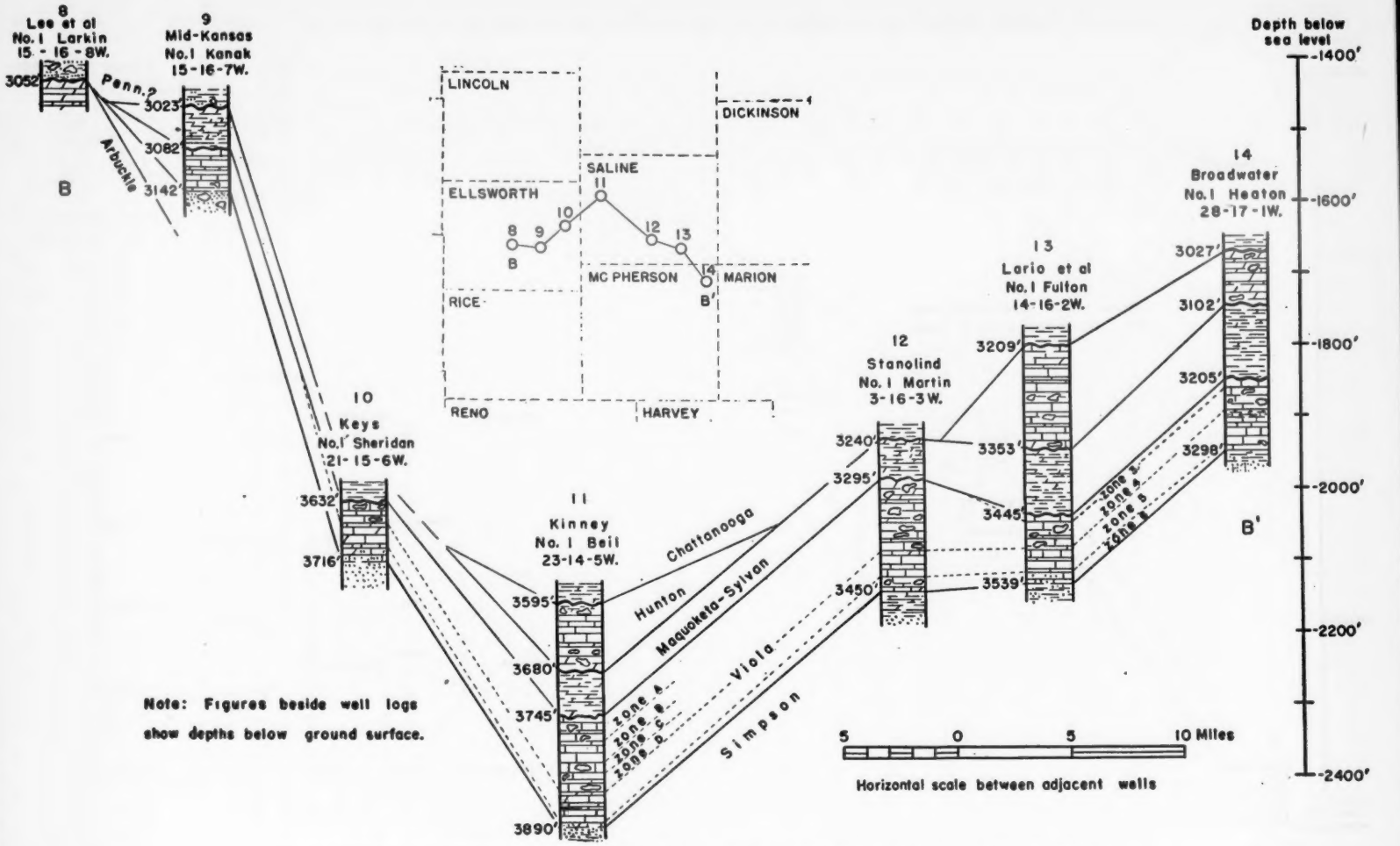


FIG. 5.—Geologic cross section of Viola and overlying strata along line *BB'* (see inset index map) in central Kansas.

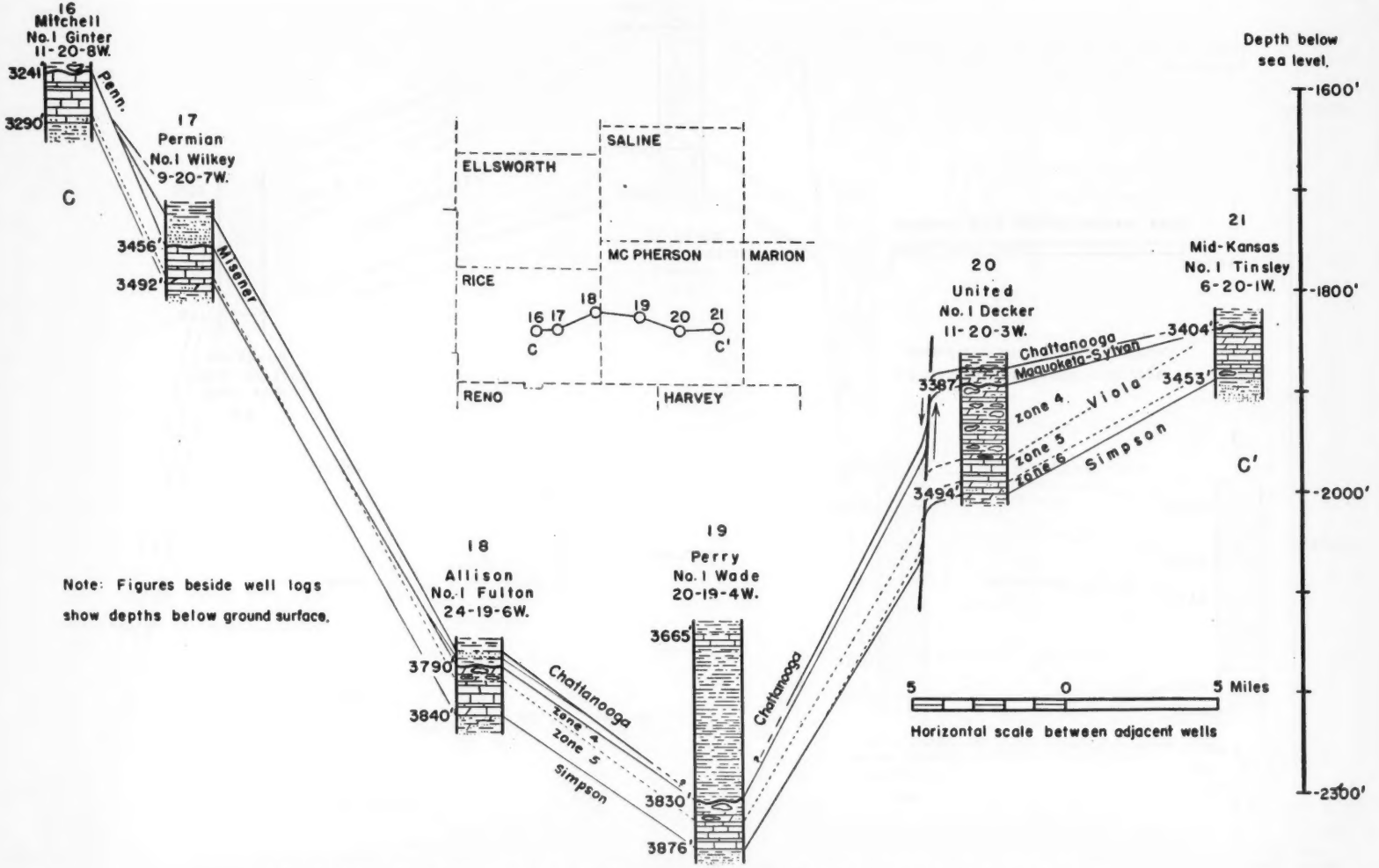


FIG. 6.—Geologic cross section of Viola and overlying strata along line *CC'* (see inset index map) in central Kansas.

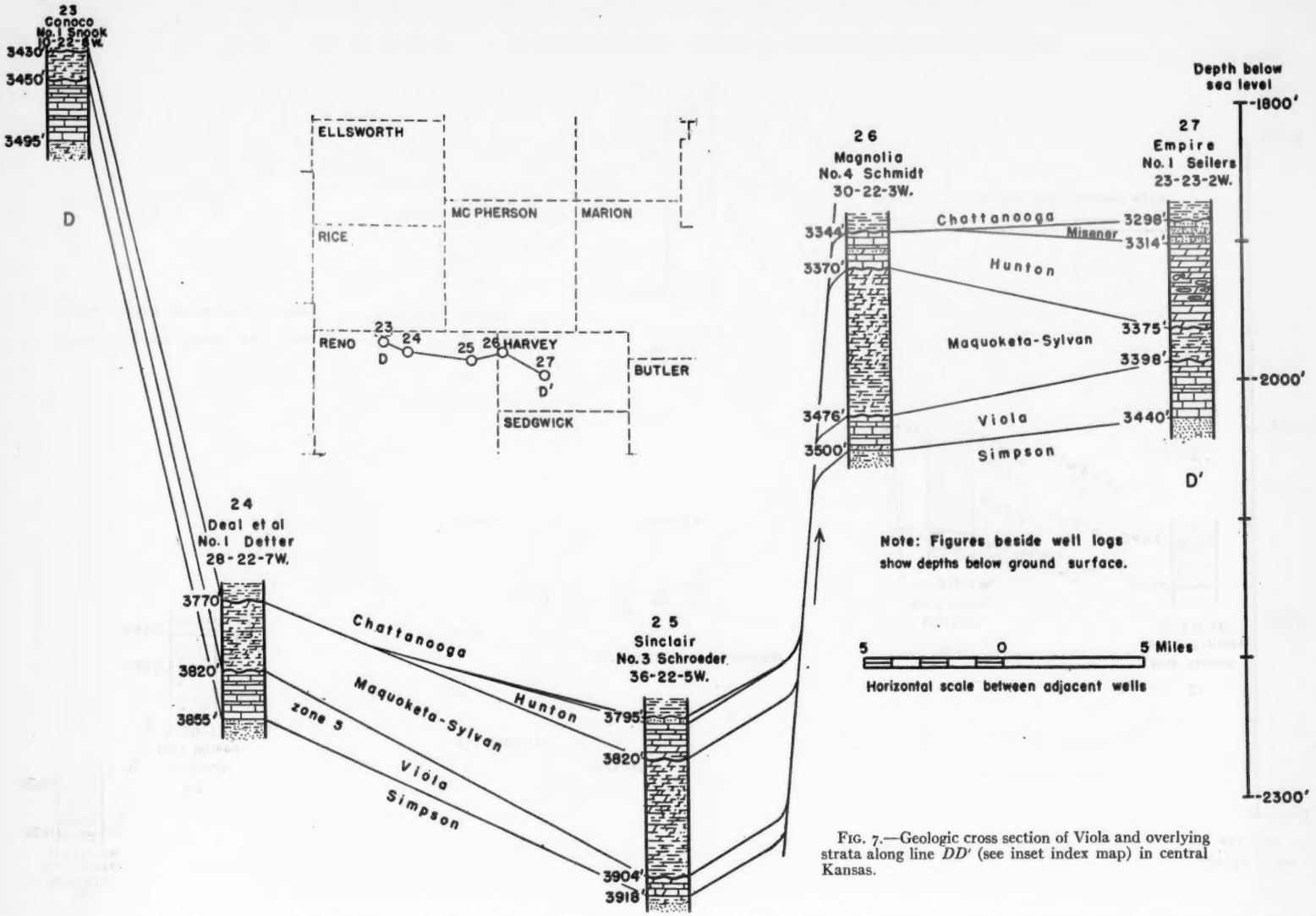


FIG. 7.—Geologic cross section of Viola and overlying strata along line *DD'* (see inset index map) in central Kansas.

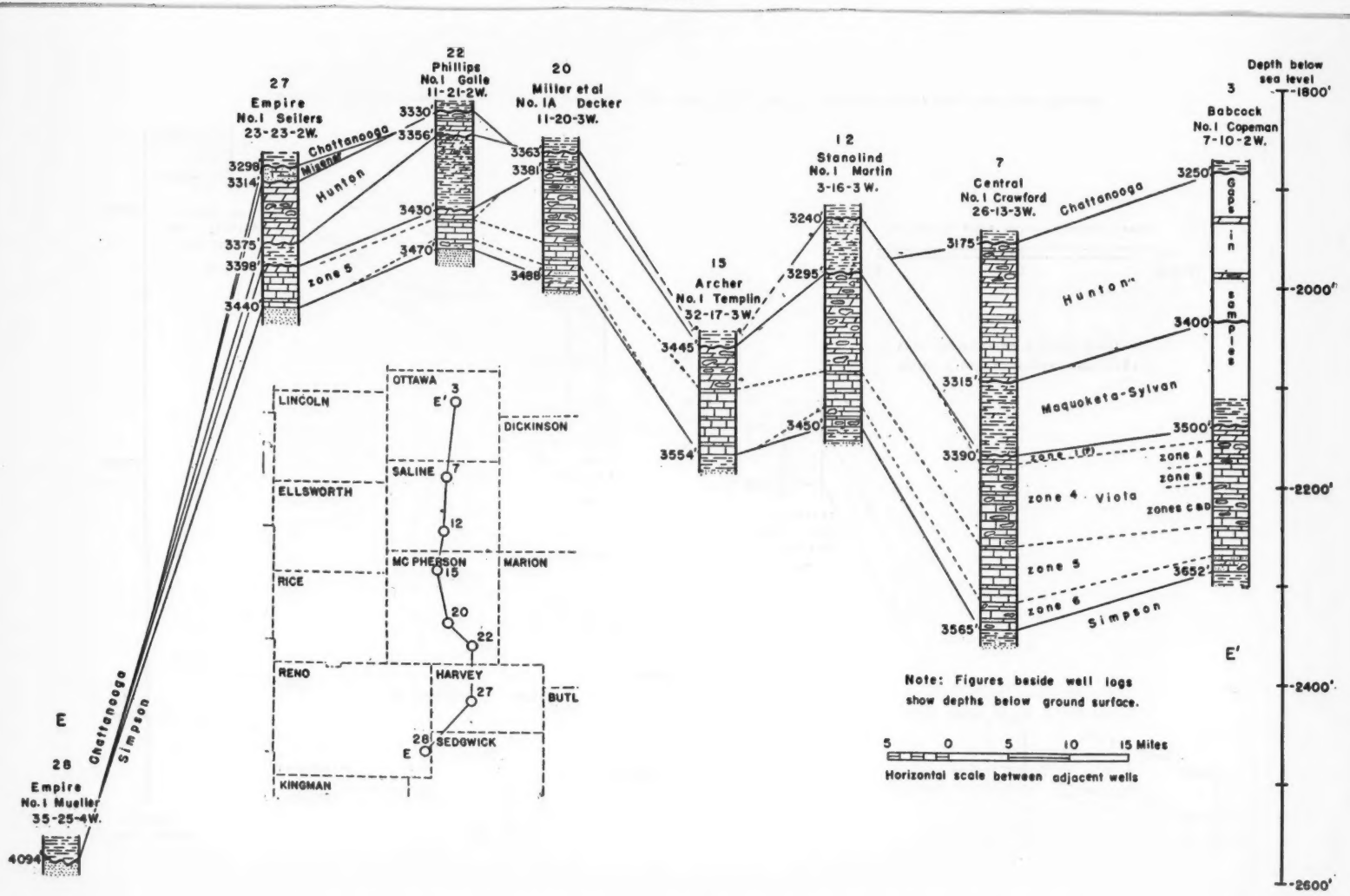


FIG. 8.—Geologic cross section of Viola and overlying strata along line *EE'* (see inset index map) in central Kansas.

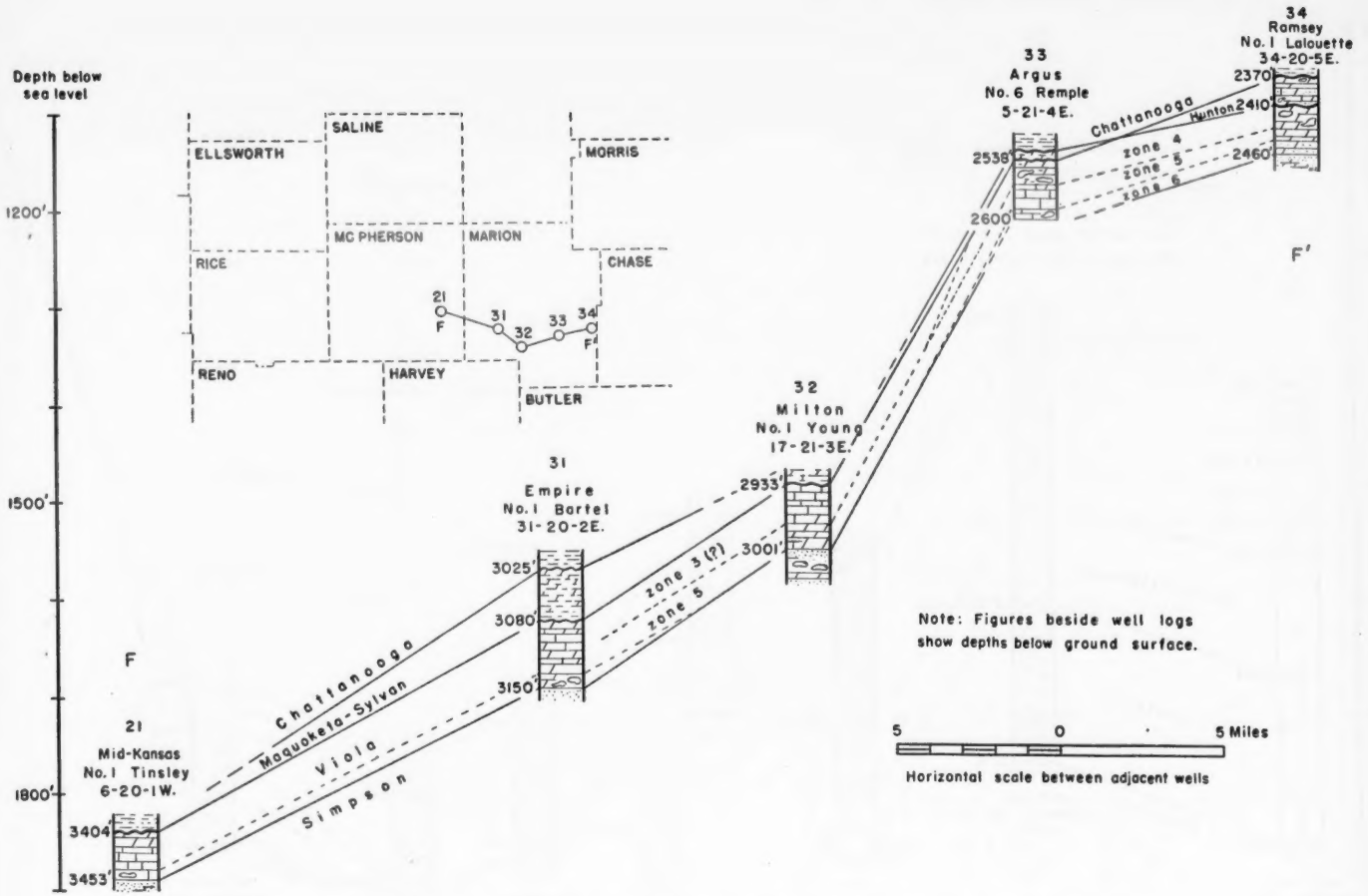


FIG. 9.—Geologic cross section of Viola and overlying strata along line *FF'* (see inset index map) in central Kansas.

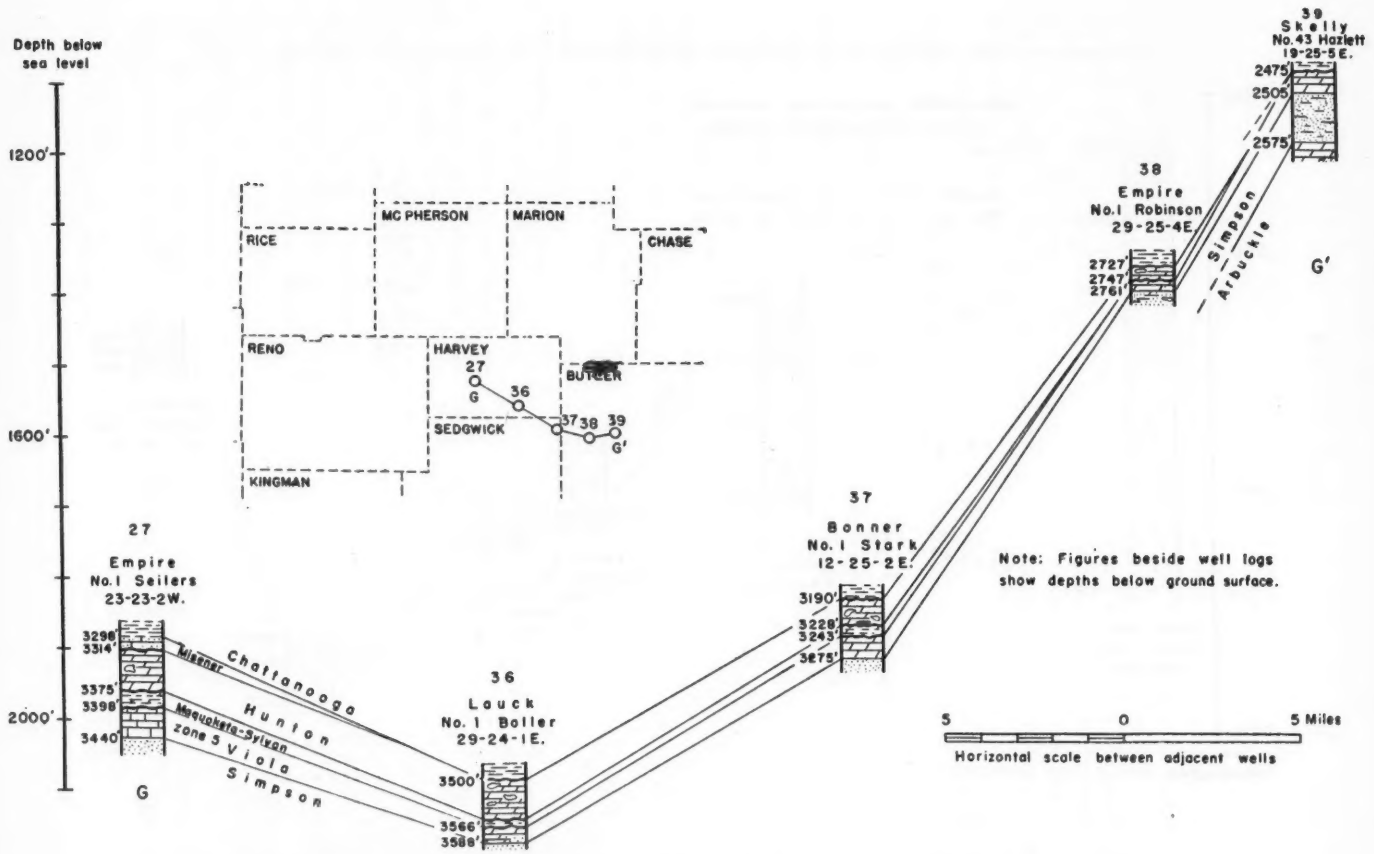


FIG. 10.—Geologic cross section of Viola and overlying strata along line *GG'* (see inset index map) in central Kansas.

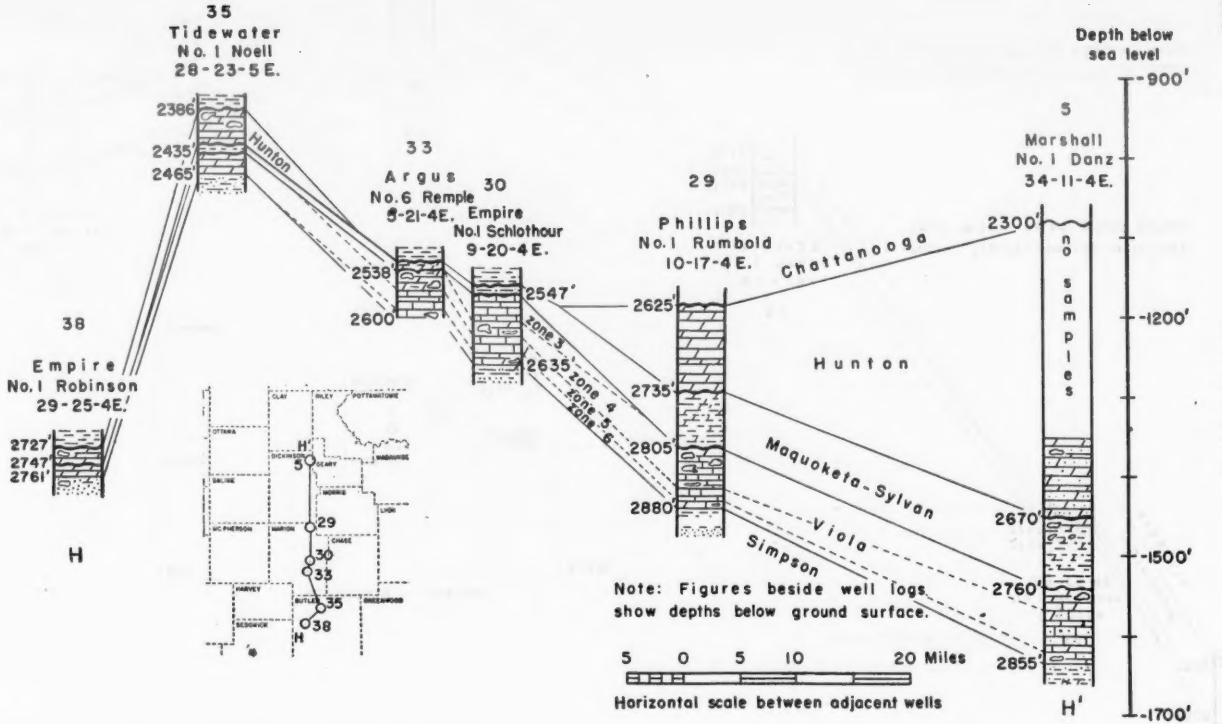


FIG. 11.—Geologic cross section of Viola and overlying strata along line *HH'* (see inset index map) in central Kansas.

In order to indicate the limitations of the maps (Figs. 1 and 2) accompanying this paper most of the wells which provided data are shown. Examination of samples from additional wells will indicate revisions that are in order for the isopachs and structure contours of Figures 1 and 2. In Figure 12 the areal extent of the different Viola zones is subject to modification, particularly of zones 1 and 3. Zone 1 may in part represent dolomitization which has occurred beneath the Viola-Maquoketa unconformity, and may include some dolomitic beds belonging in zone 3, which as now mapped includes chiefly the calcitic non-cherty beds overlying the cherty zone 4. The practice of differentiating zones on the basis of dolomitization (or lack of it) is suspect, but more satisfactory criteria are unknown for zones 1 and 3.

Paleogeography.—Viola limestones formed in widespread Mohawkian seas following the end of an epoch of Simpson sand and shale deposition over part of the Mid-Continent.

The thickest Viola deposits in central Kansas lie in the north-central part, in contrast to the thickest Siluro-Devonian Hunton section which is in the northeast.[15] There is no evidence of widespread truncation of Viola beds in the Salina basin, and it is likely that the center of the basin of deposition in Viola time lay west of that in Siluro-Devonian time.

Thicknesses of individual members vary considerably from place to place, but the zones above the lower limestone (zone 5) average somewhat thicker in the north where the section is thickest. This suggests basinward divergence with the center of the basin of deposition sinking more rapidly than the periphery, after deposition of the lower limestone member.

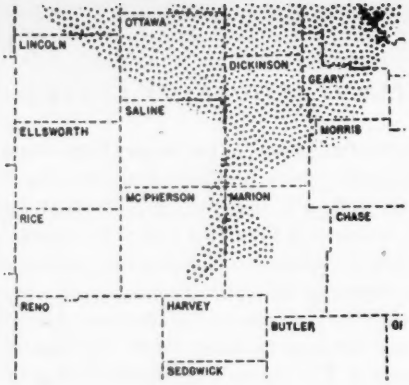
Viola strata are thinner near the Nemaha ridge than northwest of that structure due apparently to non-deposition rather than erosion. This indicates that the region of the Nemaha arch may have been sinking less rapidly than adjacent areas in Ordovician time, although the principal upward movements of the arch came in the early Pennsylvanian.

Small outliers of residual Viola beds, chiefly chert, occur on the Central Kansas uplift, indicating that the strata were originally deposited over part if not all of that structure. No such outliers of Siluro-Devonian rocks are known. The presence of these Viola outliers, comparatively close to an area of thick Viola deposits, indicates that the Central Kansas uplift was not a large positive area through Ordovician time. The absence of similar Siluro-Devonian outliers suggests that the uplift was above sea level in the mid-Paleozoic.

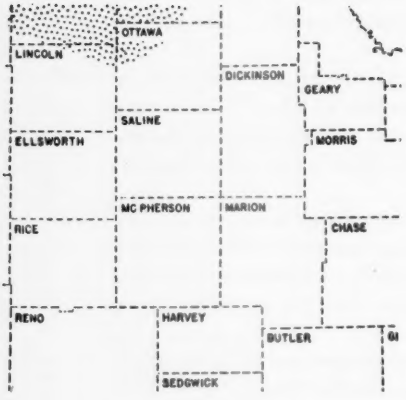
The areal extent and stratigraphic relationships of the six Viola members recognized in this paper indicate that there was discontinuous limestone deposition in central Kansas in Viola time (Fig. 12).

The basal beds (zone 6) represent the clastic facies deposited in the initial limestone-forming seas. These strata are not everywhere the same age; in some

[15] Hall Taylor, "Siluro-Devonian Strata in Central Kansas," *Bull. Amer. Assoc. Petrol. Geol.*, Vol. 30, No. 8 (August, 1946), p. 1223.



Zone 1



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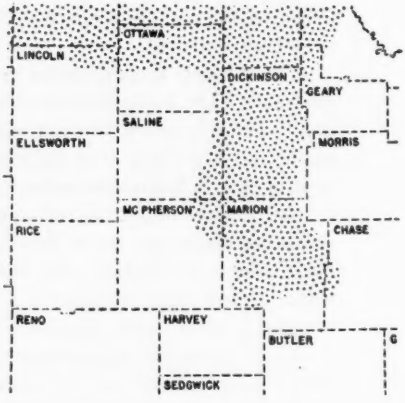

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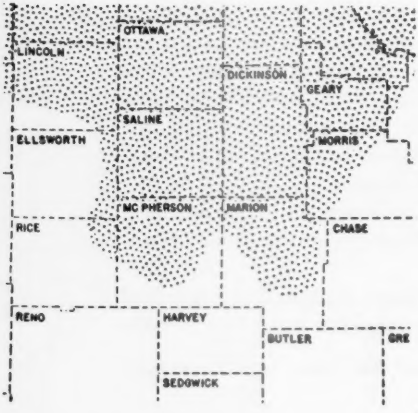
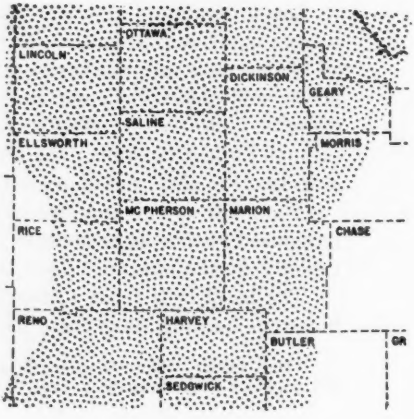


Zone 4



Zone 5

FIG. 12.—Maps showing by stippling the approximate areal extent of Viola limestone zones recognized in central Kansas.

areas they are missing altogether, probably because of non-deposition over local highs. Upon either these basal beds or Simpson strata the comparatively pure limestones of zone 5 were deposited. This is the most widespread of the Viola members, and represents a time when limestone forming seas were extensive over the Mid-Continent.

The dark-specked middle cherty member (zone 4) covers about the same area in the north as does zone 5, but does not extend as far south (Fig. 12). It is disconformable both above zone 5 and below zone 3. There is no evidence of widespread extensive erosion either before or after deposition of this cherty member. Rather it seems likely that the land remained about at sea-level, with local flexures being subjected to moderate erosion.

The middle limestone (zone 3) resembles the lower limestone (zone 5) and probably formed under about the same conditions. Its more limited areal extent, coupled with absence of evidence of extensive erosion or truncation of beds, indicate it was deposited only in the northern part of central Kansas.

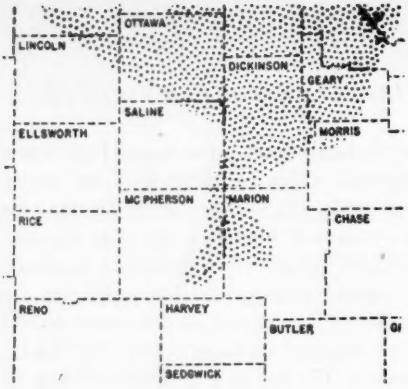
The upper cherty member (zone 2) occurs in a few wells near the northern edge of the area covered in this paper. It is younger than Viola strata on the south, and appears to have formed only in the north where lay the part of the basin receiving the thickest Viola deposits.

The upper limestone (zone 1), recognized by its abundance of coarse dolomite rhombs and crystals, may in the north be a zone of coetaneous sediments, but farther south it includes, below the Maquoketa-Sylvan unconformity, dolomitic beds which probably belong in older Viola members.

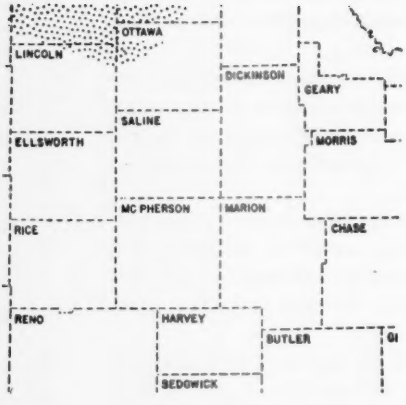
The above conclusions indicate there were at least two interruptions of sedimentation in central Kansas during Viola time. The first followed deposition of the basal clastic and lower limestone members (zones 6 and 5), the second ended deposition of the middle cherty limestone (zone 4). In the north, breaks may also occur above and below the upper cherty member (zone 2), but wells examined do not indicate whether the lithologic differences in the limestones of zones 1, 2, and 3 are the result of withdrawals and readvances of the sea or merely of changed sedimentary conditions attendant to a gradual withdrawal of the Viola seaway northward.

Oil zones.—The Viola limestone is an important oil-producing formation in Kansas, with many widely separated counties deriving a share of their production from these beds. In the central portion of the state the middle cherty and lower limestone members (zones 4 and 5) appear to be the principal producing zones, but it should be noted that not all geologists agree with the correlations assigned in this paper to the producing beds.

In Saline County a cherty dolomitic limestone which contains some oil along the Lindsborg-Salina axis is here placed in the middle cherty member (zone 4) of the Viola, but some put it in the Maquoketa. A similar situation prevails in the Lindsborg field of McPherson County. Fifteen miles farther southeast in the Ritz-Canton field some production comes from the dolomitized upper part of the



Zone 1



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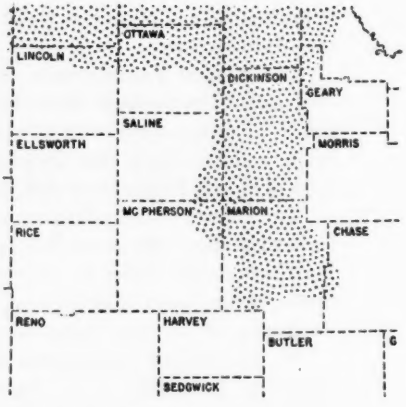
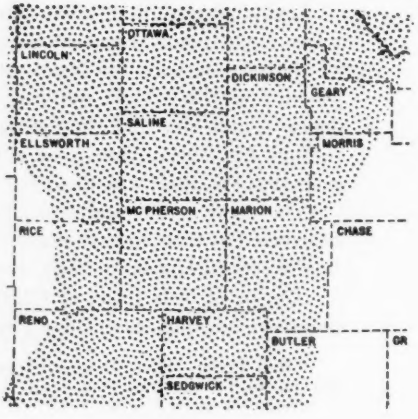


Zone 3

Zone 4



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Viola section which probably belongs in the lower limestone member (zone 5), but farther south in Harvey County where the dolomitization is not present the same beds have so far been proved non-productive.

In Sedgwick County some production which has been ascribed to the Viola is in reality coming from the Hunton. These two limestone formations are here in contact, with no intervening Maquoketa shale, and the entire limestone section has been called Viola by many geologists, who believe Siluro-Devonian strata are missing from the area.

A similar situation prevails in southern Marion County where a number of rather small old wells, long credited with Viola production, actually appear to tap oil-bearing Hunton limestones. Farther north in this county the lower limestone (zone 5) and possibly the middle limestone (zone 3) of the Viola are productive. Toward the south in Butler County in the famous Eldorado field the lower limestone (zone 5) contains oil.

OTTAWA, LINCOLN, AND SOUTHERN MITCHELL COUNTIES

Stratigraphy.—Inasmuch as the thickest and most complete Viola sections in central Kansas occur in Mitchell and adjacent counties (Fig. 1) detailed descriptions of the six zones in that region are given. Thereafter only important lateral changes in the strata in other areas are described.

Upper limestone member. Zone 1.—Lying directly beneath the Maquoketa-Sylvan shale is a medium to dark gray or brownish gray, coarsely crystalline, dolomitic limestone in which are mixed very small amounts of white to light gray, rough chert, most of which is a chalky cotton rock. This layer is comparatively uniform in texture and composition, containing many dolomite rhombs and crystals, and minor amounts of silica rock. It normally is 10–20 feet thick.

Upper cherty member. Zone 2.—Beneath the coarsely crystalline dolomitic upper limestone there occurs the topmost of three cherty members, designated zone 2. This member commonly is not over 25 feet thick, and contains as much as 75 per cent light to medium brown or gray, sharp-edged, microfossiliferous chert, most of which is smooth. There are many irregular white and gray splotches scattered through the chert, the remains of fossil fragments which are now silicified. Black specks, though rarer than the light splotches, are present in some fragments. Small light gray or tan aggregates of dolomite crystals comprise up to 25 per cent of some samples. There is also 10–35 per cent light buff or tan non-crystalline or very finely crystalline calcitic limestone. Fragments are small, this member being relatively hard and resistant to drilling. In residues most of the smooth chert is non-dolocastic, but a few rough pieces contain dolocasts. In central Kansas this member occurs only in the northern part.

Middle limestone member. Zone 3.—Crystalline to dense, light tan and gray calcitic limestone underlies the upper cherty member. Tan rhombs of dolomite and calcite are embedded in some dense limestone fragments, together with dark splotches of dirty gray limestone. Residues are small, ordinarily less than 10 per

cent, and consist of light tan and gray, spongy finely crystalline quartz grading into smooth, white or light gray chert, together with a very little pyrite. The maximum thickness of the zone is about 40 feet, in southern Mitchell County.

Middle cherty member. Zone 4.—This, the thickest and most widespread of the cherty zones, is similar in its limestone portion to zone 3, but is distinctive because of the tiny black specks scattered through the chert (Figs. 13, 14, and 15). Some fragments in the other cherty zones contain darker colored specks, but not in the abundance found in this member, and there are additional differences. Zone 2 cherts are commonly microfossiliferous, gray or brown and smooth, with conchoidal fractures abundant. These zone 4 cherts are mostly gray or tan, with both smooth and rough surfaces. Zone 6 cherts are moderately smooth, brown but unevenly colored, with myriads of minute darker brown spots mixed in a somewhat lighter brown matrix.

In southern Mitchell County wells a four-fold subdivision of zone 4 is feasible, but farther south and east over most of central Kansas the zone thins, perhaps through disappearance of upper layers, and the subdivisions are not recognizable. However, they are described here in order to permit comparison by those examining wells farther north in Kansas where the entire Mohawkian limestone section is comparatively thick, and this cherty member is prominent. The changes from zone to zone are gradual rather than abrupt.

SUBDIVISIONS OF ZONE 4

Zone A. Upper one-fifth of zone. About 50 per cent light tan, finely crystalline calcitic limestone containing a few brown dolomite rhombs, and 50 per cent chert which is of two principal varieties that are gradational into each other. One form is a light tan or gray, somewhat microfossiliferous, smooth sharp-edged dense chert containing black specks and small white cotton-like spots (Fig. 13, fragment No. 1). The other is the same color, but is round-edged, much rougher surfaced, and reflects tiny pin points of light from some microcrystalline quartz (Fig. 13, fragment No. 2). The same black specks are present as in the smooth chert, but the white cotton-like patches are missing. In residues dolocasts are absent in the smooth chert, and minute and uncommon in the rough variety.

Zone B.—Tan, crystalline to dense calcitic limestone, containing a few brown dolomite rhombs and a little gray or white drusy spongy quartz which grades into the microcrystalline variety of zone A. Also a few clear angular to frosted sub-rounded sand grains. Noncherty (Fig. 14).

Zone C.—About 60 per cent limestone which is similar to that in zone B, and 40 per cent light gray to white, darkly specked cherts of the types described in zone A, with the rough variety preponderant, and soft enough to be mashed with a needle. In residues the rough chert contains minute dolocasts, and the smooth type also shows a few such rhombic holes (Fig. 15).

Zone D.—Basal two-fifths of zone. At the top this is similar to zone C, but chert percentages decrease downward, and the smooth sharp edged variety is relatively the more abundant. Toward the base there is some increase of brown dolomite rhombs in the calcitic limestone.

Lower limestone member. Zone 5.—Light tan, buff, or gray crystalline, dense or flaky calcitic limestones mixed with some brown dolomite crystals comprise

this member. Near the top the beds are very coarsely crystalline (Fig. 16, sample), but lower in the zone finer-grained and even dense layers are common. Some pieces contain irregular dirty gray splotches, perhaps the remains of carbonaceous material enveloped during formation of the sediments. Insoluble material, mostly gray drusy quartz, constitutes less than 5 per cent of samples except in a few feet of basal beds which contain as much as 20 per cent light gray to white, rough, minutely and sparingly dolocastic cotton-like quartz rock with small amounts of sub-rounded sand (Fig. 16, residue). Broken fragments show that the cotton-like texture of the quartz rock is a surface feature grading into light or medium buff, solid, finely sucrose cherty central portions. Silicified microfossils are common.

This cherty layer may deserve rank commensurate with the numbered zones, particularly if the basal Viola is considered a chert-free pure limestone, in which case this layer, together with zone 6, would be pre-Viola. But this narrow band of chert can not be traced over wide areas, and since it forms a relatively small percentage of samples which otherwise are identical with overlying beds it is here considered a part of zone 5.

Lower cherty or *basal clastic member. Zone 6.*—This basal zone of the limestone section contains varying proportions of calcitic and dolomitic limestone, chert, sand, and drusy quartz (Fig. 17). In some wells there is also a little pyrite and dark gray to black hard waxy shale in which are embedded a few sub-rounded, slightly frosted sand grains. The calcitic limestone is light tan to buff, and dense to finely crystalline as in the overlying member. Scattered through it are rhombs of brown dolomite which in some wells become sufficiently abundant to form crystalline aggregates of dolomitic limestone. Colorless quartz sand, with grains varying from clear and angular to frosted and sub-rounded, comprises as much as 20 per cent of some samples. A few grains occur separately, others are in aggregates held together by calcium carbonate cement, and still others are scattered through the limestome fragments. Most samples also contain a little drusy quartz.

The chert is distinctive and varies in amount, percentages normally increasing toward the base where chert comprises as much as 50 per cent of some samples. Like higher cherts this one is light tan to buff brown, sharp-edged, sparingly dolocastic in residues, and commonly smooth-surfaced though some pieces are rough. Unlike other cherts the surfaces of most pieces are stippled and unevenly colored, and consist of myriads of minute light to medium brown spots of all shapes, though commonly somewhat rounded, in a light tan to light gray matrix. Ordinarily the spots are so close they touch and form somewhat contiguous masses. They are semi-translucent along thin edges, and the matrix is opaque. In places this chert resembles coffee in which cream has curdled, although the spots of "cream" are darker brown than the "coffee" matrix. Under low power magnification the chert pieces appear to break with a smooth, conchoidal fracture,but high power shows that the fractures in some fragments go around instead of across the individual stipples or spots, just as might occur in oölites, but this is not an oölitic chert although in places it has a micro-oölitic appearance.

The zones just described occur in the Siedhoff *et al.* Grief well No. 1 (SW. ¼, SE. ¼, Sec. 16, T. 8 S., R. 10 W.) which has about 250 feet of Viola strata (Fig. 4, well No. 1).

LOG OF SIEDHOFF ET AL. GRIEF NO. 1, SEC. 16, T. 8 S., R. 10 W.

Depth (Feet)	*Descriptions of Zones*
3,725	CHATTANOOGA SHALE
-3,754	No samples. Upper limestone member (zone 1) of Viola is probably in this interval.
-3,769	UPPER CHERTY MEMBER (ZONE 2) OF VIOLA. About 50 per cent tan crystalline calcitic limestone, and 50 per cent tan smooth to rough very microfossiliferous chert
3,769	TOP OF MIDDLE LIMESTONE MEMBER (ZONE 3)
-3,780	About 60 per cent tan crystalline calcitic limestone, 35 per cent gray dolomitic flaky shale (cave ?) and 5 per cent drusy quartz
-3,787	Similar to above, but drusy quartz and chert constitute 25 per cent of samples
-3,805	Calcitic limestone with about 10 per cent drusy quartz
3,805	TOP OF MIDDLE CHERTY MEMBER (ZONE 4)
-3,825	ZONE A. About 50 per cent tan or gray, dark-specked, smooth and solid to rough and porous, microfossiliferous chert, and 50 per cent tan crystalline calcitic limestone containing a few embedded brown dolomite rhombs
-3,845	ZONE B. Light tan coarsely crystalline calcitic limestone admixed with a little drusy quartz
-3,859	ZONE C. Crystalline to dense calcitic limestone admixed with as much as 40 per cent grayish white, rough to smooth, moderately black-specked chert which in residues contains some tiny dolocasts
-3,874	No samples
-3,934	ZONE D. About 50 per cent brown crystalline dolomitic limestone, 25 per cent tan calcitic limestone, and 25 per cent light gray chert similar to that in zone C
3,934	TOP OF LOWER LIMESTONE MEMBER (ZONE 5)
-3,970	About 75 per cent tan calcitic and 25 per cent brown dolomitic crystalline limestone, with a few fragments of drusy quartz
3,970	TOP OF LOWER CHERTY MEMBER (ZONE 6)
-3,984	About 60 per cent dense to crystalline calcitic limestone with a few embedded brown dolomite rhombs, 20 per cent tan stippled chert, and 20 per cent angular to subrounded sand
3,984	TOP OF SIMPSON (DECORAH ?) SHALES. Grayish green waxy shale

Structure.—Viola strata dip east and northeast off the flanks of the Central Kansas uplift, are farthest below sea-level in a trough in western Ottawa County (Fig. 2), and rise gradually farther east. They are thickest in Mitchell County, and thin toward the south and east, chiefly through disappearance of some upper parts of the section.

DICKINSON COUNTY AND AREAS NORTH AND EAST

Stratigraphy.—Over most of the northeastern part of central Kansas middle Ordovician limestones are more than 100 feet thick (Fig. 1). They thin gradually toward the south, chiefly through disappearance of some upper parts of the section.

The upper limestone member (zone 1) is 10–20 feet thick and similar to the same zone farther west, but the dolomite rhombs are somewhat less coarsely crystalline, and normally are buff-brown instead of gray in color. The upper cherty member (zone 2) is absent. Some of the middle limestone member (zone 3) is likewise missing, but many wells have 10–15 feet of chert-free calcitic and dolomitic limestone remaining in this zone. The middle cherty member (zone 4)

is between 20 and 35 feet thick, and is abundantly microfossiliferous, but the characteristic black specks, although present, are not common. The chert is tan or gray, with smooth- and rough-surfaced varieties intermixed. In residues a few thin beds are quite dolocastic.

The lower limestone member (zone 5) continues with undiminished thickness across the area, and even thickens somewhat toward the northeast where small amounts of grayish green shale and quartz sand occur in the lower part of the limestone. Fragments from some of these shaly layers will, if dropped in water, swell and crumble in the manner of bentonites. Beds of altered volcanic ash occur in Ordovician rocks in the eastern United States, and it is possible that similar layers are present in the Mid-Continent. Since correlations are based on lithologies it might appear that the top of the shale should mark the top of the Simpson (Decorah?) formation, and possibly fossils, if available, would support such a view. However, it appears that the lower cherty member (zone 6) is present below these somewhat shaly and sandy beds. Hence the small amounts of arenaceous and argillaceous material are considered clastic parts of the zone 5 limestone, though it is recognized that correlations with Iowa and Missouri strata may eventually indicate a Decorah or Platteville age for these somewhat shaly layers.

The lower cherty member (zone 6) is 10–25 feet thick, and contains more limestone and less chert than in wells at the west. In some samples chert forms less than 10 per cent of the cuttings, but the few fragments present show typically the myriads of tiny brown stipples in a lighter brown matrix. This zone overlies beds of green or gray waxy shale and sand, probably of Decorah age.

Logs of three wells in Riley, Pottawatomie, and Wabaunsee counties in the northeastern part of this area are reproduced in order to permit comparison of studies in northeastern Kansas[16] with zones described in this paper. One well, the Empire Oil Company's Schwalm No. 1 (SW. ¼, Sec. 19, T. 12 S., R. 11 E.) in Wabaunsee County, lies east of the area mapped for this report.

LOG OF CORONADO OIL COMPANY'S PARKS NO. 1, SEC. 16, T. 10 S., R. 8 E. (FIG. 4, WELL NO. 6)

Depth (Feet)	*Descriptions of Zones*
1,764	BASE OF MAQUOKETA-SYLVAN SHALE. TOP OF VIOLA LIMESTONE
–1,770	UPPER LIMESTONE MEMBER (ZONE 1). Crystalline dolomitic limestone
–1,780	No samples
–1,810	MIDDLE CHERTY MEMBER (ZONE 4). Tan microfossiliferous chert mixed with buff crystalline limestone. Dolomite predominates in upper part, calcite and chert in lower
–1,870	LOWER LIMESTONE MEMBER (ZONE 5). Tan crystalline calcitic limestone containing a few brown dolomite rhombs. Below 1,850 feet some gray green waxy shale and a few sand grains are mixed with limestone
–1,880	LOWER CHERTY OR BASAL CLASTIC MEMBER (ZONE 6). Tan to brown dense limestone with some brown stippled chert. Little pyrite
1,880	TOP OF SIMPSON FORMATION (DECORAH?). Chiefly green and brown waxy shale

LOG OF J. A. TURNER'S UMSCHEIDT NO. 1, SEC. 32, T. 8 S., R. 9 E.

[16] Wallace Lee, *op. cit.*, pp. 35–40, 60, and 61.

Depth (Feet)	*Descriptions of Zones*
1,747	BASE OF MAQUOKETA-SYLVAN SHALE. TOP OF VIOLA LIMESTONE
–1,790	MIDDLE CHERTY MEMBER (ZONE 4). Tan crystalline dolomitic limestone mixed with white to tan microfossiliferous chert. Relatively non-cherty zone from 1,752–1,759 feet is probably zone B of areas on west
–1,850	LOWER LIMESTONE MEMBER (ZONE 5). Light tan to white crystalline calcitic limestone. A little gray and green shale below 1,822 feet, and much shale from 1,830–1,835 feet are placed in Decorah by some geologists
–1,875	LOWER CHERTY OR BASAL CLASTIC MEMBER (ZONE 6). Tan to brown crystalline calcitic limestone with small amounts of green or gray shale and brown chert
1,875	TOP OF SIMPSON FORMATION. Gray shale

LOG OF EMPIRE OIL COMPANY'S SCHWALM NO. 1, SEC. 19, T. 12 S., R. 11 E.

Depth (Feet)	*Descriptions of Zones*
3,285	BASE OF MAQUOKETA-SYLVAN SHALE. TOP OF VIOLA LIMESTONE
–3,307	MIDDLE LIMESTONE MEMBER (ZONE 3). Buff crystalline dolomitic limestone. May belong partly in zone 1
–3,328	MIDDLE CHERTY MEMBER (ZONE 4). About 60 per cent brown smooth chert containing a few black specks, and 40 per cent brown crystalline dolomitic limestone
–3,389	LOWER LIMESTONE MEMBER (ZONE 5). Buff crystalline dolomitic and calcitic limestone. Gray bentonite-like shale is mixed with limestone in beds at 3,364–3,370 and 3,383–3,389 feet (Decorah shale?)
–3,400	LOWER CHERTY OR BASAL CLASTIC MEMBER (ZONE 6). Brown crystalline dolomitic limestone mixed with some dark brown chert and grayish green shale
3,400	TOP OF SIMPSON FORMATION. Sand

Structure.—The regional thinning of the Viola limestone toward the south and southeast, and thickening toward the west is shown in Figure 1. Dip of the strata is toward the west (Fig. 2) and is partially a reflection of the late Paleozoic uplift of the Nemaha arch. Minor folds trend northeast-southwest across Dickinson, Clay, and Riley counties but limited drilling has not revealed fully their areal extent.

SALINE AND ELLSWORTH COUNTIES

Stratigraphy.—Only the lower parts of the middle Ordovician limestone section of Mitchell County have wide areal extent toward the south in Saline and Ellsworth counties. Zone 1 is thin or absent, zones 2 and 3 are missing over most of the area, zones 4, 5, and 6 are variable (Fig. 12), and their total thicknesses range from about 150 feet in the northeast to zero on high areas in Ellsworth County.

A thin coarsely crystalline dolomitic limestone, interpreted as the upper limestone member (zone 1), appears in rotary samples from the Central Oil and Gas Company's Crawford well No. 1 (NE. ¼, Sec. 26, T. 13 S., R. 3 W.) at 3,390 feet, but was not recognized elsewhere in the two counties. The upper cherty member (zone 2) likewise is missing. Five to 10 feet of the middle limestone (zone 3) occur in parts of eastern Saline County, but farther west this member also is gone. The middle cherty limestone (zone 4) is widespread and has a maximum thickness exceeding 100 feet. The chert of this zone contains more black specks here than on the north and east (Fig. 18), and is separable into two divisions. The upper part contains black-specked gray chert, some of which in residues is smooth and solid, the rest rough and dolocastic. The lower part is also black-specked, but is

ordinarily tan or brown, smooth and solid, with many tiny indistinct microfossils packed so closely together as to give the fragments a somewhat mottled or lace like appearance which resembles some of the chert in the lower cherty member (zone 6). The lower limestone (zone 5) is 35–50 feet thick, with buff or gray crystalline calcitic limestone which is little changed from the region farther north. The basal beds (zone 6) are chiefly brown calcitic and dolomitic limestones with minor amounts of chert, sand and shale, the whole being less than 25 feet thick. In many wells the distinctive chert is missing, and this lowest zone is recognized by the change from calcitic limestone to calcitic and dolomitic strata containing small amounts of sand and shale. In other wells some stippled chert is present, and overlies a Simpson sand in which is a gray, dark-specked, smooth chert that in residues contains large dolocasts.

Structure.—Thicknesses and dips of middle Ordovician limestones, shown on the isopach and structure maps (Figs. 1 and 2), are a continuation of trends noted in Mitchell County on the north. Viola strata disappear on the flanks of the Central Kansas uplift in western Ellsworth County, and are also missing from the tops of highs in central and southern Ellsworth County. The lower beds (zones 5 and 6) extend farthest onto the flanks of these uplifted areas, a relationship well shown in the Mid-Kansas Oil and Gas Company's Kanak well No. 1 (SW. ¼, Sec. 15, T. 16 S., R. 7 W.) where, beneath the shale which ends at 3,082 feet, there are 45 feet of crystalline calcitic limestone, interpreted as zone 5, and 15 feet of tan limestone with some stippled chert of zone 6 (Fig. 5, well No. 9), in contact at 3,142 feet with Simpson subangular sands and gray dark-specked dolomite bearing chert. No zone 4 cherts are present.

Viola sections more than 150 feet thick occur farthest south in T. 16 S., R 3 W. on the site of the northeast-southwest trending Lindsborg-Salina anticline in central Saline County (Fig. 1). Downdip about 6 miles east there are only 95 feet of limestones. The thickening occurs in the middle cherty member (zone 4), with zones 5 and 6 remaining normal. Two wells which illustrate this relationship are the Stanolind Oil and Gas Company's Martin No. 1 (SE. ¼, Sec. 3, T. 16 S., R. 3 W.) which is near the crest of the anticline (Figs. 5 and 8, well No. 12), and the Lario *et al.* Fulton No. 1 (NW. ¼, Sec. 14, T. 16 S., R. 2 W.) in a trough on the east (Fig. 5, well No. 13).

LOG OF STANOLIND OIL AND GAS COMPANY'S MARTIN NO. 1,
SEC. 3, T. 16 S., R. 3 W.

Depth (Feet)	*Descriptions of Zones*
3,295	BASE OF MAQUOKETA-SYLVAN SHALE. TOP OF VIOLA LIMESTONE
–3,395	MIDDLE CHERTY MEMBER (ZONE 4). Gray (upper part) and tan (lower part), black specked chert mixed with brown and tan dolomitic and calcitic limestone
–3,430	LOWER LIMESTONE MEMBER (ZONE 5). Tan calcitic limestone containing brown dolomite rhombs
–3,450	LOWER CHERTY MEMBER (ZONE 6). Brown calcitic limestone with dolomite rhombs and a few pieces of brown-stippled chert
3,450	TOP OF SIMPSON FORMATION (DECORAH?). Green waxy shale with a little limestone

LOG OF LARIO ET AL. FULTON NO. 1, SEC. 14, T. 16 S., R. 2 W.

Depth (Feet)	*Descriptions of Zones*
3,445	BASE OF MAQUOKETA-SYLVAN SHALE. TOP OF VIOLA LIMESTONE
–3,452	MIDDLE LIMESTONE MEMBER (ZONE 3). Tan crystalline calcitic limestone
–3,485	MIDDLE CHERTY MEMBER (ZONE 4). Black-specked, tan chert mixed with tan calcitic limestone
–3,525	LOWER LIMESTONE MEMBER (ZONE 5). Tan or gray, crystalline to dense limestone
–3,539	BASAL CLASTIC MEMBER (ZONE 6). Buff to brown limestone mixed with some sand
3,539	TOP OF SIMPSON FORMATION (DECORAH?) Greenish black waxy shale

Oil zones.—Among Saline County oil fields there are three comparatively small pools—Salina (T. 14 S., R. 2 W.), Mentor (T. 15 S., R. 3 W.), and Olsson (T. 16 S., R. 3 W.)—which some credit with Viola production, but others place the productive beds in the Maquoketa. All three fields lie along the trend of the Lindsborg-Salina axis, and reveal somewhat similar stratigraphic relationships which have been described in the section on stratigraphy.

Illustrating the stratigraphic sequence of these controversial strata are cable-tool samples from the Detrick Company's Sudendorf well No. 1 (SE. ¼, Sec. 30, T. 14 S., R. 2 W.) and the Bronk Company's Thalander well No. 1 (SE. ¼, Sec. 10, T. 16 S., R. 3 W.). The Sudendorf well, near the edge of the Salina pool, produced only a little oil, but this came from a cherty dolomitic limestone which was topped at 3,265 feet, and which lay beneath a gray partly dolomitic shale of Maquoketa age. The producing zone placed by some geologists in the Maquoketa, is believed to be the middle cherty member (zone 4) of the Viola. Below it are pure limestones which are universally accepted as Viola in age, and which in this paper are placed in the lower limestone member (zone 5).

The Thalander well penetrated about 230 feet of Chattanooga and Maquoketa shales from 3,055 to 3,285 feet. The lowest 60 feet of this sequence was quite dolomitic. It is placed in the Maquoketa. At 3,285 feet the bit penetrated a cherty dolomitic limestone, and the hole filled with 1,700 feet of oil in 4 days, but did not make a producing well. This oil bearing formation appears to be the same as that which produces in the Salina pool about 10 miles to the northeast, and is probably the middle cherty member (zone 4) of the Viola, although some geologists place it in the Maquoketa. It is about 100 feet thick, with the lowest 25 feet containing calcitic as well as dolomitic limestone. Between 3,385 and 3,435 feet there is a tan, pure, dense to crystalline calcitic limestone which is the lower limestone member (zone 5) of the Viola. Below this are 10 feet of brown and tan limestone with some sand, and at 3,445 feet there appear the dark green waxy shales of the Simpson.

MCPHERSON AND RICE COUNTIES

Stratigraphy.—Lithologic variations create some uncertainties in correlation of the middle Ordovician limestones of McPherson and Rice counties. In addition, the strata thin toward the south, apparently through partial, and in some places complete, disappearance of all but the lower limestone member (zone 5). Coupled

with this thinning is local thickening of beds interpreted as belonging in the middle cherty member (zone 4). These factors combine to introduce more uncertainties in correlations here than in the area on the north.

The upper limestone member (zone 1), identified by its coarsely crystalline texture and abundance of dolomite rhombs and crystals, is about 5–10 feet thick in eastern and southeastern McPherson County, but is absent elsewhere. As much as 25 feet of dolomitic limestone are logged at the tops of sections in wells in this area, but only the coarsely crystalline upper few feet are considered equivalent to the upper limestone, the rest are placed in the lower limestone (zone 5).

The upper cherty member (zone 2) does not occur in these two counties. About 15 feet of the upper limestone (zone 3) appear in northeastern McPherson County, but elsewhere this zone is missing.

The black-specked middle cherty member (zone 4) is absent in southern McPherson County, and does not extend as far west onto the flanks of the Central Kansas uplift as does the underlying zone 5, but elsewhere this member is prominent (Figs. 12 and 19). It is thickest over the sites of two arches, the Lindsborg-Salina axis (T. 16 and 17 S., R. 3 W.) and the Voshell trend (T. 19 and 20 S., R. 3 W.), which were folded subsequent to deposition of the beds.

The foregoing statements, it should be noted, are predicated on correlations which, just as in Saline County at the north, are not accepted by some who have studied the beds. In northern McPherson and northeastern Rice counties dirty gray, cherty, shaly, dolomitic limestones (Fig. 20) overlie clean, tan, crystalline, calcitic limestones belonging in the Viola, and in some wells underlie typical Maquoketa-Sylvan shales. This exceptional, shaly dolomitic limestone contains large amounts of rough, black-specked, dirty gray chert. Residues are shaly in places, commonly dolocastic (Fig. 21), and resemble those obtained from some siliceous dolomitic shaly zones of the overlying Maquoketa-Sylvan formation, in which some geologists place these beds. However, the black specked chert which, it is believed, can be traced laterally into definite Viola strata (Fig. 8), is here considered indicative that the layers belong in the middle cherty member (zone 4) of the Viola, but correlations by lithology alone can not be considered entirely conclusive, and diagnostic fossils were not observed. The cherty beds are thickest, 60–80 feet, in T. 19 and 20 S., R. 3 W. (Figs. 6 and 8, well No. 20), and thin east and west. They, together with lower Viola strata, are the oil producers in the Lindsborg and Salina pools.

An impure thin shale separates the middle cherty limestone (zone 4) and the underlying lower limestone member (zone 5) in some wells in northern McPherson County, suggesting that there is a break between these two members. This shaly layer is of irregular occurrence, but appears in enough wells to indicate it is not cave. In the Simmons *et al.* Anderson well No. 1 (SW. ¼, Sec. 14, T. 17 S., R. 1 W.) it lies between 3,410 and 3,418 feet; in the Broadwater Drilling Company's Heaton well No. 1 (SE. ¼, Sec. 28, T. 17 S., R. 1 W.) it is between 3,245 and 3,250

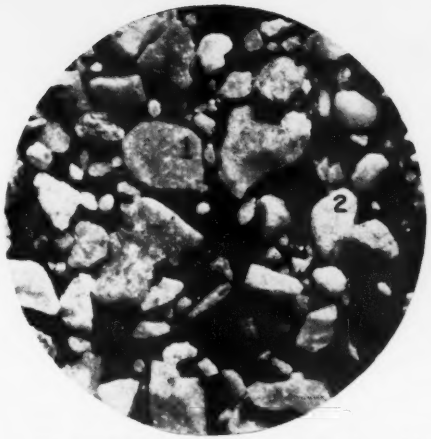


FIG. 13.—Photomicrograph (×10) of sample of zone A in zone 4. Note (1) sharp-edged microfossiliferous chert and (2) rounded detrital chert with microcrystalline quartz. Copeman well No. 1, Sec. 7, T. 10 S., R. 2 W., Ottawa Co., depth 3,515–3,518 feet.

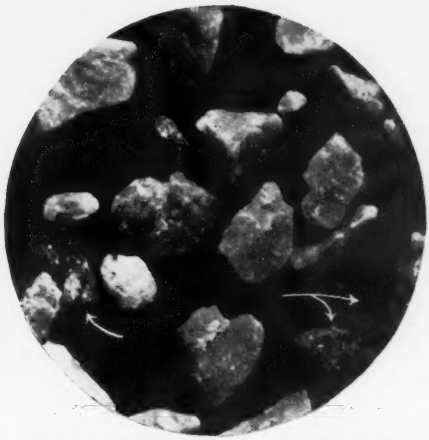
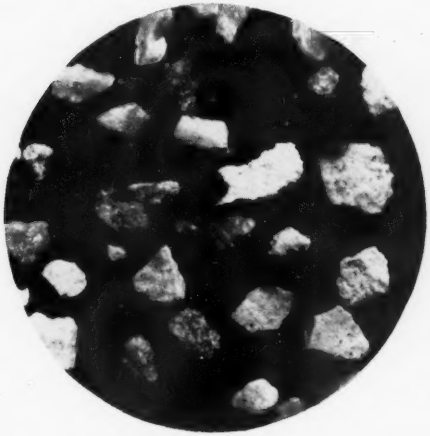


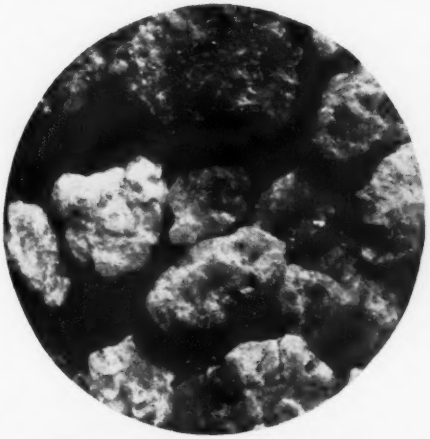
FIG. 14.—Photomicrograph (×10) of sample of dense to crystalline, calcitic limestone with some dolomite rhombs (near arrowheads) in zone B of zone 4. Copeman well No. 1, Sec. 7, T. 10 S., R. 2 W., Ottawa Co., depth 3,540–3,549 feet.



Sample

Residue

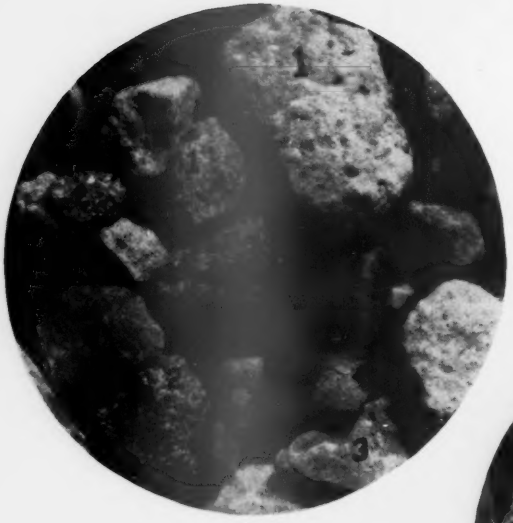
FIG. 15.—Photomicrographs (×10) of zone C in zone 4 showing limestone similar to zone B, and chert with tiny black specks, minute dolocasts, and both rough and smooth surfaces. Copeman No. 1, Sec. 7, T. 10 S., R. 2 W., Ottawa Co., depth 3,562–3,569 feet.



Sample

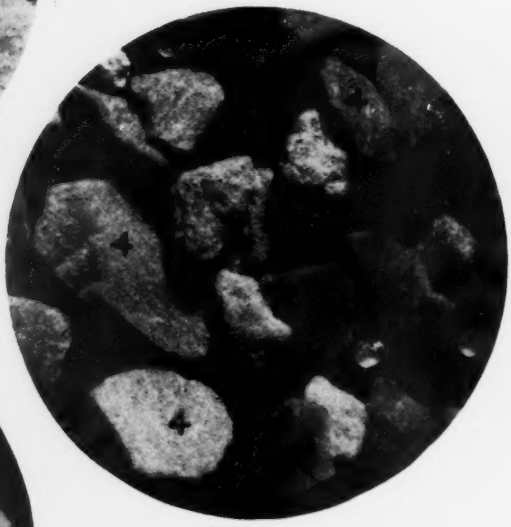
Residue

FIG. 16.—Photomicrographs (×10) of zone 5 showing (in sample) coarsely crystalline limestone typical of Viola, and (in residue) rough cherty fragments and few sand grains occurring near base of zone. Copeman No. 1, Sec. 7, T. 10 S., R. 2 W., Ottawa Co., depth (sample) 3,599–3,607 and (residue), 3,625–3,632 feet



Sample

FIG. 17 (Left and below).—Photomicrographs (×12) of zone 6 showing (1) calcitic limestone with few (dark) dolomite rhomb inclusions, (2) aggregates of (brown) dolomite rhombs with calcite cement, (3) dense and flaky calcitic limestone, and (4) stippled chert. Copeman well No. 1, Sec. 7, T. 10 S., R. 2 W. Ottawa Co., depth 3,632–3,652 feet.



Residue

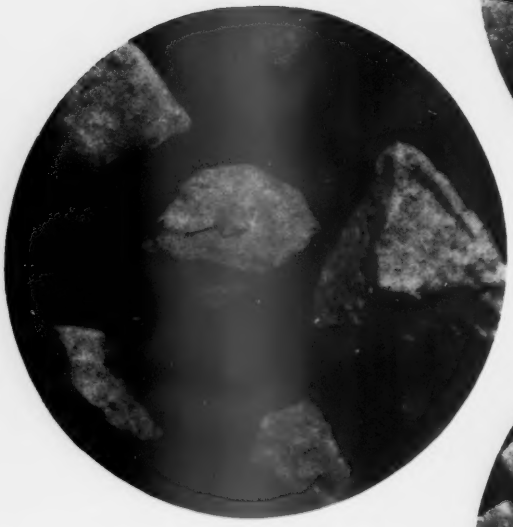
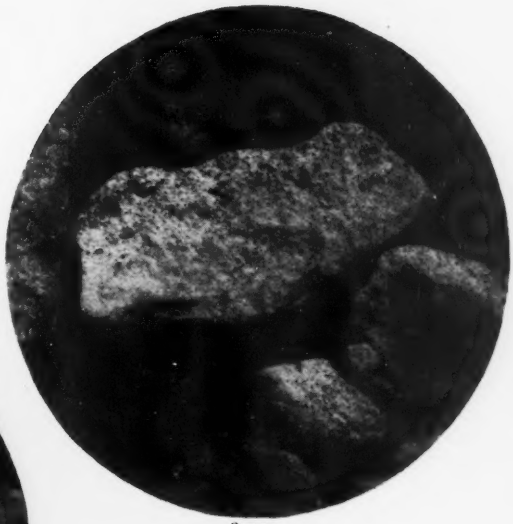


FIG. 18 (Above).—Photomicrograph (×12) of sample of zone 4 showing tiny black specks in chert. Note (near arrowhead) 4-rayed microfossil, probably part of hexactinellid sponge spicule. Crawford well No. 1, Sec. 20, T. 13 S., R. 3 W., northern Saline Co., depth 3,400–3,405 feet.

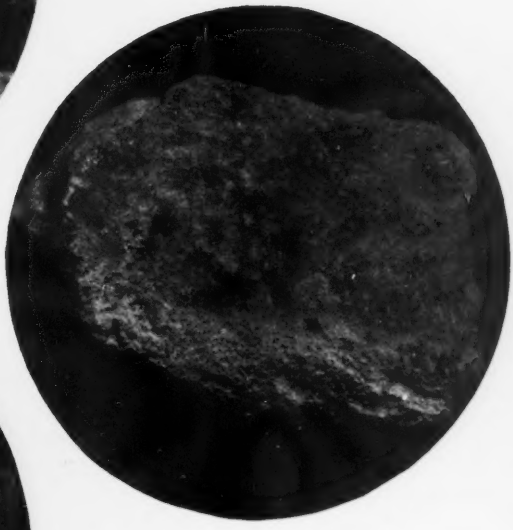
FIG. 19 (Right).—Photomicrograph (×12) of sample of zone 4. Note (1) white microfossiliferous inclusions in (brown) chert, (2) black speck in (tan) chert, and (3) crude banding in dolomitic limestone. Pierce well No. 1, Sec. 29, T. 20 S., R. 7 W., Rice Co., depth 3,580–3,585 feet.

FIG. 20 (Right and below).—Photomicrographs (×12) of silty, dark-specked chert and dolomitic limestone considered part of zone 4. Note (in sample) many tiny dark specks in large (tan) central chert fragment, and (in residue) numerous tiny dolocasts and crude banding by dark silty layers. Fulton well No. 1, Sec. 24, T. 19 S., R. 6 W., Rice Co., depth 3,794–3,798 feet.



Sample

Residue



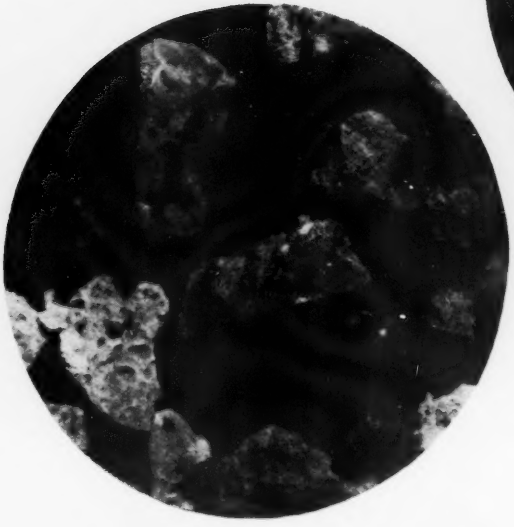


FIG. 21 (Above).—Photomicrograph (×12) of residue of dirty gray, rough, black-specked zone 4 chert fragment. Note dolocastic light gray (weathered surface?) zone near bottom of picture. Templin well No. 1, Sec. 32, T. 17 S., R. 3 W., McPherson Co., depth 3,475–3,488 feet.

FIG. 22 (Left).—Photomicrograph (×12) of residue showing dark specks, white inclusions and sand grains, embedded in a zone 6 chert. Galle well No. 1, Sec. 11, T. 21 S., R. 2 W., southern McPherson Co., depth 3,460–3,465 feet.

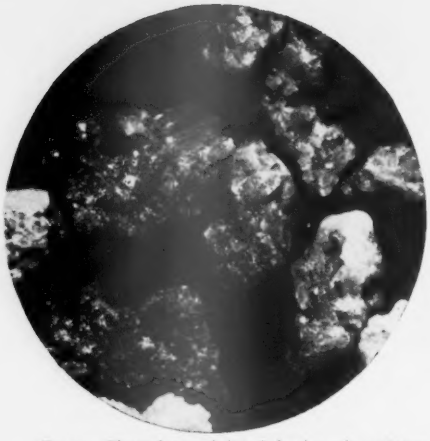


FIG. 23.—Photomicrograph (×10) showing zone 5 mixture of brown dolomite crystals (note large rhomb near center), and tan flaky calcite. Williams well No. 1, Sec. 17, T. 25 S., R. 2 W., Sedgwick Co., depth 3,929–3,934 feet.

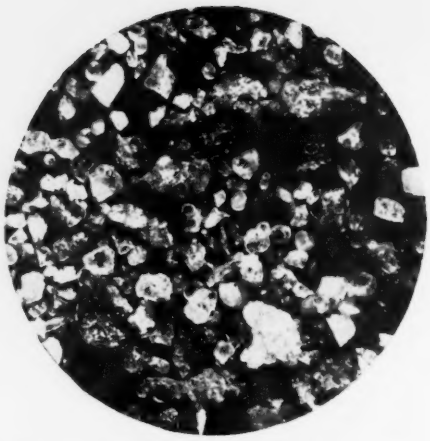


FIG. 24.—Photomicrograph (×10) of angular to subrounded sand in residue of zone 6. Boller well No. 1, Sec. 29 T. 24 S., R. 1 E., Harvey Co., depth 3,584–3,588 feet.

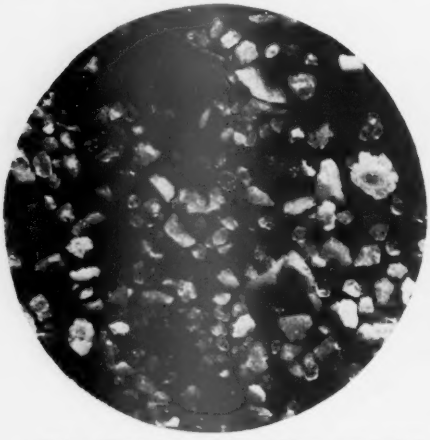


FIG. 25.—Photomicrograph (×10) of drusy quartz and subangular sand in residue from strata interpreted as zone 5. Gale well No. 1, Sec. 8, T. 25 S., R. 3 E., Butler Co., depth 3,207–3,210 feet.

FIG. 26.—Photomicrograph (×10) of residue of Chattanooga shale showing rounded black spores in gray shale. Gale well No. 1, Sec. 8, T. 25 S., R. 3 E., Butler Co., depth 3,137–3,145 feet.

FIG. 27.—Photomicrograph (×10) of residue of gray-green waxy upper Simpson (Decorah?) shale. Danz well No. 1, Sec. 34, T. 11 S., R. 4 E., Dickinson Co., depth 2,892–2,902 feet.

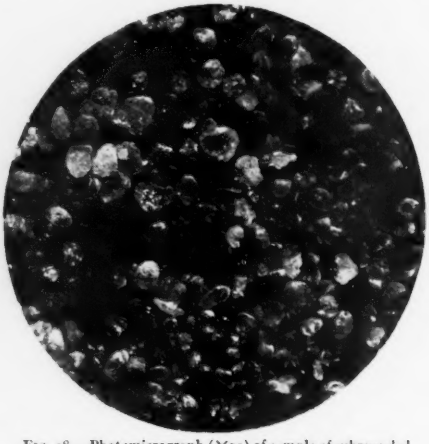


FIG. 28.—Photomicrograph (×10) of sample of subrounded to angular Simpson sand. Copeman well No. 1, Sec. 7, T. 10 S., R. 2 W., Ottawa Co., depth 3,688–3,695 feet.

feet; and in the McPherson Oil and Gas Company's Norling well No. 1 (NE. ¼, Sec. 9, T. 17 S., R. 2 W.) it is near the bottom of the hole at about 3,585 feet. Some regard this shale merely as cave, but it seems too common at a particular horizon to be so explained.

Some of those who place in the Viola the limestone which contains specked chert (zone 4), put the underlying rather pure limestone (zone 5) in the Simpson. Thus Hiestand[17] notes that the "speckled chert" of the "Viola limestone" occurs in the northern part of the Voshell field (Sec. 34, T. 20 S., R. 3 W.), but that over much of that region a "white-to-gray, coarsely crystalline, dolomitic limestone" underlies the "Viola limestone," is "included in the Simpson group," and is "considered a correlative of the Prosser." This underlying limestone is the lower limestone member (zone 5) of the Viola as defined in this present paper, and the top of the Simpson is placed still lower in the section at the point where relatively pure sands or shales appear. Thus the separation is based on lithology, because paleontologic evidence is as yet considered inconclusive.

The lower limestone (zone 5) is the most widespread member in the region, covering McPherson and much of Rice County, and extending farthest onto the flanks of the high areas associated with the Central Kansas uplift. It is commonly 20 to 40 feet thick, and reaches 60 feet in T. 17 S., R. 3 W., in northern McPherson County. It is a coarsely crystalline, tan and brown limestone, largely calcitic but partly dolomitic in the southern parts of the two counties. It displays some irregular black or brownish red splotches, perhaps the remains of microfossils enclosed by the sediments during formation.

Comparison of wells in northern and central McPherson County shows that this lower limestone (zone 5) is thicker where the overlying middle cherty member (zone 4) is thin, and *vice versa*, suggesting possibility of a disconformable relationship, and adding credence to the view that there was a break in sedimentation between zones 4 and 5. This variation is illustrated by logs of Jeff Archer's Templin well No. 1 (SE. ¼, Sec. 32, T. 17 S., R. 3 W.) in northern McPherson County and the Mid-Kansas Oil and Gas Company's Jones well No. 1 (NE. ¼, Sec. 26, T. 19 S., R. 3 W.), 12 miles south.

LOG OF JEFF ARCHER'S TEMPLIN NO. 1, SEC. 32, T. 17 S., R. 3 W.

Depth (Feet)	*Descriptions of Zones*
3,223–3,445	CHATTANOOGA SHALE. No Maquoketa-Sylvan shale recognized in this well
–3,447	MISENER SANDY ZONE. Sand, limestone, chert and shale
–3,488	VIOLA LIMESTONE. MIDDLE CHERTY MEMBER (ZONE 4). Crystalline, calcitic and dolomitic limestone mixed with gray rough chert which in residues is dolocastic, slightly silty, and soft enough to be scratched with a needle.
–3,498	Transition zone. Chert and limestone as above with some crystalline and drusy quartz. Disconformity (?)
–3,554	LOWER LIMESTONE MEMBER (ZONE 5). Tan crystalline limestone
3,554	TOP OF SIMPSON FORMATION (DECORAH?). Green and gray waxy shale

[17] T. C. Hiestand, "Voshell Field, McPherson County, Kansas," *Bull. Aser. Assoc. Petrol. Geol.*, Vol. 17, No. 2 (February, 1933), p. 174.

LOG OF MID-KANSAS OIL AND GAS COMPANY'S JONES NO. 1,
SEC. 26, T. 19 S., R. 3 W.

Depth (Feet)	*Descriptions of Zones*
3,445	BASE OF CHATTANOOGA SHALE
–3,480	MAQUOKETA-SYLVAN FORMATION. Dolomitic gray shale
–3,560	VIOLA LIMESTONE. MIDDLE CHERTY MEMBER (ZONE 4). Crystalline brown dolomitic limestone mixed with black-specked, smooth to rough, microfossiliferous chert which is dolocastic in residues
–3,590	LOWER LIMESTONE MEMBER (ZONE 5). Tan crystalline limestone, sandy in lower part
3,590	TOP OF SIMPSON FORMATION (DECORAH?). Green shale

The lower or basal cherty member (zone 6) is missing over parts of Rice and McPherson counties, and is thin elsewhere. In some wells there is an abrupt change from the limestone of zone 5 to underlying Simpson sands and shales; in other wells a thin impure limestone, without chert but with some sand and drusy quartz, lies at the base of zone 5. These sandy and quartzose layers are here placed in zone 6, since that member includes the basal clastics of the limestone section, but it is recognized that the quartzose layers may not be coetaneous with beds containing the brown-stippled chert by which zone 6 is identified farther north.

In southern McPherson County a different type of basal chert is present. The minute stippling and uneven coloring of areas to the north is replaced by a more uniform brown; dark red and black specks increase in prominence; and frosty white microfossiliferous inclusions are common (Fig. 22). Another chert, which likewise contains dark-colored specks, is associated with Simpson sands and shales in this region, but the first-named chert occurs above these Simpson beds. It is mixed with limestone, just as is the stippled chert of more northern areas, and is therefore placed in the basal beds of the limestone sequence. It is considered approximately the time equivalent of the stippled chert, and its different appearance may be the result of different conditions prevailing at the time of deposition of basal limestone beds.

Structure.—Southward thinning of the Ordovician limestones, together with dips into the trough of the Conway syncline which trends north-south through western McPherson County, continue trends that were noted in the area on the north (Figs. 1 and 2). In Rice County the strata disappear on the flanks of the Central Kansas uplift and associated high structures. In McPherson County the beds are raised steeply over the Voshell anticline where faulting, with the upthrown side on the east, has produced vertical variations of hundreds of feet in strata of closely adjacent wells. For example, in Sec. 33, T. 20 S., R. 3 W. one well reached the top of the Viola at 1,782 feet below sea-level, yet less than ¼ mile west another well topped the same formation at 2,245 feet below sea-level, a vertical variation of more than 450 feet.

Oil zones.—Four major pools of McPherson County are credited with Viola production—Lindsborg (T. 17 S., R. 3 and 4 W.), McPherson (T. 18 S., R. 2 W.), Ritz-Canton (T. 19 and 20 S., R. 1 and 2 W.), and Voshell (T. 20 and 21 S., R. 3 W.).

In the Lindsborg field the principal producing zone is a cherty and shaly

dolomitic limestone which overlies a clean calcitic limestone, the two layers being considered zones 4 and 5 respectively of the Viola. However, as in Saline County on the north, some geologists place this cherty dolomitic limestone in the Maquoketa, and thus credit this overlying formation with much of the oil production. These differences in view have been discussed in the preceding sections. They are illustrated by the Carter Oil Company's Hogland well No. 1 (NW. ¼, Sec. 8, T. 17 S., R. 3 W.), in which the bit penetrated a few feet of sandy strata after passing through a thick shale section, and then entered a cherty limestone at 3,349 feet. Oil is found in the upper 30 feet of this cherty bed which is here considered zone 4 of the Viola, but by some is placed in the Maquoketa. Beneath this bed is a clean crystalline limestone of generally accepted Viola age (zone 5 of this paper), and still lower at about 3,470 feet there appears the top of the Simpson.

In the Ritz-Canton field the Viola is one of four important producing zones. It is a comparatively pure limestone in which the upper few feet normally are dolomitized. The entire section is placed in the lower limestone member (zone 5), with the possible exception of the top few feet which may belong in zone 1. Oil commonly occurs in the upper heavily dolomitized part. A representative hole in this field is Tom Palmer's Winn well No. 2 (NW. ¼, Sec. 7, T. 20 S., R. 1 W.) which originally was completed in 1931 in the Mississippian limestone, producing potentially 2,770 barrels of oil per day. Later it was deepened to 3,418 feet in the Viola, and produced for a time from the dolomitized upper part of that formation (zone 5) at about 3,400–3,405 feet. Still later it was deepened into the Simpson without satisfactory production.

RENO COUNTY

Stratigraphy.—Comparatively thin non-cherty calcitic and dolomitic limestones form most of the Viola sections in Reno County. The dolomitized upper limestone member (zone 1) is missing in much of the area. In the southern part, dolomitic limestones are common, but they represent a gradational facies change from the calcitic limestones of zone 5 farther north, although a few feet at the top of some wells may be remnants of zone 1. The upper cherty, upper limestone and middle cherty members (zones 2, 3, and 4) do not appear in this area. The lower limestone (zone 5) has a maximum thickness of about 50 feet and is the only member present over much of the county. It is crystalline, gray or black splotched and calcitic in the north, browner and more dolomitic in the south. Bits of pyrite are disseminated through the limestone, and in some wells in the central and southern parts of the county a white or light tan smooth chert forms as much as 10 per cent of samples. The lower cherty or basal clastic member (zone 6) is poorly developed in Reno County. Some wells show thin sandy zones at the base of the limestone section, but the stippled chert is absent, and in many wells the change from calcitic or dolomitic limestone to the underlying Simpson sand or shale is abrupt.

Structure.—The axis of the Conway syncline, which extends north and south

across western Saline and McPherson counties, turns and dips southwest in Reno County toward a region named the Dodge City basin by McClellan.[18] West of this trough, on the flanks of the Central Kansas uplift the Ordovician strata rise, then disappear through truncation. They are also gone from part of southeastern Reno County, in T. 25 S., R. 4 W., where the Empire Oil and Gas Company's Mueller well No. 1 (SW. ¼, Sec. 35, T. 25 S., R. 4 W.) shows Chattanooga shale resting on Simpson sand (Fig. 8, well No. 28). In northern Reno County a small local high is revealed by Continental Oil Company's Snook well No. 1 (SW. ¼, Sec. 10, T. 22 S., R. 8 W.), in which the Viola limestone occurs between 3,455 and 3,500 feet, about 200 feet higher structurally than in near-by wells on the north.

Structure contours in western Reno County (Fig. 2) are located from driller's logs, and accuracy of the lines is limited, but Viola strata occur in the Dodge City basin, and the edge of the formation curves around the south side of the Central Kansas uplift approximately as shown.

Oil zones.—Most of the oil produced in the northeastern townships of Reno County comes from rocks other than Viola. The large Burrton field taps Mississippian and Siluro-Devonian deposits, but the smaller Buhler field is credited with production from Viola and Simpson strata.[19] Most of this latter oil, however, seems to be Simpson. The Viola, which here is a calcitic or somewhat dolomitic limestone, is recorded as the producer in a few wells such as the Westgate-Greenland Oil Company's Wood well No. 2 (NE. ¼, Sec. 36, T. 22 S., R. 5 W.) at 3,898 to 3,906 feet. But in most holes the bit passes through the Viola limestone and finds oil at the top of the Simpson sand, as in the Amerada-Westgate Company's Johns test No. 1 (SE. ¼, Sec. 25, T. 22 S., R. 5 W.) where a well with a 912-barrel potential was completed in the top of the Simpson at about 3,898 feet.

MARION COUNTY

Stratigraphy.—In the northern part of Marion County the middle Ordovician limestones are similar to sections in near-by Dickinson and McPherson counties. In the south, however, the strata undergo rather abrupt lateral changes from calcitic to dolomitic facies, and from cherty to non-cherty beds, making correlations uncertain in places. A cherty member, interpreted as zone 4, separates two limestones, believed to be zones 3 and 5, in some wells but is missing in other holes, and there is no corresponding decrease in over-all thickness of the section. Either the remaining limestones represent two members between which is an undetected break, or one member disappears and the other thickens in areas where the cherty zone is absent. In either case a disconformity is present. An alternate possibility, which is without supporting evidence, is that the cherty zone 4 becomes non-

[18] Hugh W. McClellan, "Subsurface Distribution of Pre-Mississippian Rocks of Kansas and Oklahoma," *Bull. Amer. Assoc. Petrol. Geol.*, Vol. 14, No. 12 (December, 1930), pp. 1535–56.

[19] Walter A. Ver Wiebe, "Exploration for Oil and Gas in Western Kansas during 1945," *Kansas Geol. Survey Bull. 62* (1946), p. 65.

cherty but does not disappear. Logs illustrating the changes are presented near the end of this section.

A few wells have thin layers of coarsely crystalline dolomitic limestone, typical of zone 1, at the top of the section, but in most of the county this member is missing. The upper cherty member (zone 2) likewise is gone. The middle limestone member (zone 3) is recognized in much of the county where it overlies black-specked cherty beds of zone 4, but in the southwest the middle cherty member is missing, and the total section, which does not thin abruptly with disappearance of the cherty beds, may contain both middle and lower limestones (zones 3 and 5). In areas where the middle limestone (zone 3) can be recognized by its occurrence above the black-specked cherty zone it commonly is tan, crystalline to flaky, calcitic limestone, whereas the lower limestone (zone 5) in the same areas is browner and somewhat more dolomitic. On the southwest in the noncherty section the limestone commonly is calcitic in the upper parts and more dolomitic in the lower, lending credence to the view that it comprises both zones 3 and 5.

The middle cherty member (zone 4) occurs over most of Marion County except the southern and southwestern parts. It is gray or tan, and microfossiliferous, but the dark specks which characterize this chert are less common than in areas on the north and west.

The lower limestone (zone 5) is the most widespread member, occurring in wells in all parts of the county. It is a brown or tan crystalline limestone, calcitic in the north, more dolomitic in the south.

The lower cherty or basal clastic member (zone 6) is widely but irregularly distributed. Many wells have 5 to 20 feet or more of unevenly colored brown chert, others show only a thin sandy zone at the base of the section, and some have clean breaks between the limestone and underlying green shale and sand. In a few wells a dark-specked brown chert, which in residues contains large sharp-edged dolocasts, lies below the limestone section. It resembles a chert which occurs in Simpson strata, and is considered a part of that older formation. Its numerous dark specks and large rhombs of dolomite distinguish it from the unevenly colored but non-speckled and only slightly dolocastic chert of zone 6.

Logs of three wells, one in the northern and two in the southern parts of Marion County, illustrate the stratigraphic relationships described in the preceding paragraphs. In the north the White Eagle Oil and Refining Company's Ucker test No. 1 (NW. ¼, Sec. 24, T. 17 S., R. 2 E.) penetrated 100 feet of Viola strata believed to represent zones 3, 4, 5 and 6.

LOG OF WHITE EAGLE OIL AND REFINING COMPANY'S UCKER NO. 1,
SEC. 24, T. 17 S., R. 2 E.

Depth (Feet)	*Descriptions of Zones*
3,080	BASE OF MAQUOKETA-SYLVAN SHALE. TOP OF VIOLA LIMESTONE
–3,085	MIDDLE LIMESTONE MEMBER (ZONE 3). Tan, crystalline to dense, calcitic limestone. Little gray drusy quartz in residue
–3,125	MIDDLE CHERTY MEMBER (ZONE 4). Gray, smooth to rough, sparingly black-specked

Depth (Feet)	*Descriptions of Zones*
	chert, moderately dolocastic in residues, mixed with gray and brown, dense calcitic limestone containing a few dolomite rhombs
–3,145	LOWER LIMESTONE MEMBER (ZONE 5). Brown and tan, dense to crystalline, calcitic limestone with trace of drusy gray quartz
–3,180	LOWER CHERTY MEMBER (ZONE 6). Unevenly colored, brown, sharp-edged chert mixed with calcitic and dolomitic limestone
3,180	TOP OF SIMPSON FORMATION. Sands and green shale

In southern Marion County the Empire Oil and Refining Company's Schlothour well No. 1 (SW. $\frac{1}{4}$, NE. $\frac{1}{4}$, Sec. 9, T. 20 S., R. 4E.) penetrated 88 feet of strata (Fig. 11, well No. 30) similar to those in the Ucker No. 1, but with considerable variations in thickness.

LOG OF EMPIRE OIL AND REFINING COMPANY'S SCHLOTHOUR NO. 1, SEC. 9, T. 20 S., R. 4 E.

Depth (Feet)	*Descriptions of Zones*
2,547	BASE OF MAQUOKETA-SYLVAN SHALE. TOP OF VIOLA LIMESTONE
–2,581	MIDDLE LIMESTONE MEMBER (ZONE 3). Tan calcitic limestone with many cleavage faces
–2,600	MIDDLE CHERTY MEMBER (ZONE 4). Gray microfossiliferous sparingly speckled chert mixed with brown calcitic and dolomitic limestone
–2,620	LOWER LIMESTONE MEMBER (ZONE 5). Tan and brown calcitic limestone enclosing many dolomite rhombs
–2,635	LOWER CHERTY MEMBER (ZONE 6). Unevenly colored tan chert mixed with brown and gray, calcitic and dolomitic limestone
2,635	TOP OF SIMPSON FORMATION. Sands and green waxy shales

In southwestern Marion County the Empire Oil and Refining Company's Bartel well No. 1 (NW. corner, SE. $\frac{1}{4}$, Sec. 31, T. 20 S., R. 2 E.) shows that the middle cherty member (zone 4) has disappeared (Fig. 9, well No. 31), but the remainder of the section is as thick as in the Schlothour No. 1 which is 15 miles northeast. Either zones 3 and 5 are present and undiminished in total thickness in the Bartel No. 1, although the boundary between them is not apparent in samples, or one of the zones has thickened sufficiently to fill the interval, from which the other is gone. In either case erosional breaks are indicated both above and below the middle cherty member (zone 4).

LOG OF EMPIRE OIL AND REFINING COMPANY'S BARTEL NO. 1, SEC. 31, T. 20 S., R. 2 E.

Depth (Feet)	*Descriptions of Zones*
3,080	BASE OF MAQUOKETA-SYLVAN SHALE. TOP OF VIOLA LIMESTONE
–3,111	INTERPRETED AS MIDDLE LIMESTONE MEMBER (ZONE 3). About 60 per cent brown and gray dolomitic limestone, and 40 per cent tan calcitic limestone
–3,135	INTERPRETED AS LOWER LIMESTONE MEMBER (ZONE 5). Brown dolomitic limestone
–3,150	LOWER CHERTY MEMBER (ZONE 6). Brown unevenly colored chert mixed with gray dolomitic limestone
3,150	TOP OF SIMPSON FORMATION. Sand

Structure.—The westward dip of Viola strata over much of Marion County (Fig. 2) reflects structural control from the Nemaha arch which is on the east. The beds are gone from parts of the crest of the arch as a result of post-Viola

erosion. Such stripped highs occur in Chase and Butler counties and probably extend into eastern and southern Marion County, but the wells examined do not delimit fully the exact extent of these areas.

Oil zones.—Several rather small oil fields are scattered over Marion County. Some, like Fanska (T. 17 S., R. 1 E.) and Lost Springs (T. 17 S., R. 4 E.), produce from Pennsylvanian or Mississippian strata, but others, such as Hillsboro (T. 19 S., R. 3 E.), Covert-Sellers (T. 21 S., R. 4 E.), Florence (T. 21 S., R. 5 E.), and Peabody (T. 22 S., R. 4 E.), find oil in pre-Mississippian rocks. Most of these pools were opened many years ago in the 1920's, and samples are likely to be inadequate, with many gaps, or missing altogether. However, a few good samples are available from some pools, and more exist from near-by dry holes. These indicate that the oil is coming from both Hunton and Viola strata.

In the Hillsboro field, the Shell Oil Company's Funk well No. 2 (SW. ¼, Sec. 7, T. 19 S., R. 3 E.) initially produced 77 barrels per day from crystalline dolomitic and calcitic limestone between 2,825 and 2,841 feet, total depth. It is believed the Hunton is missing here, and that the producing strata belong in the lower limestone (zone 5) and possibly also in the middle limestone (zone 3) of the Viola which here lies directly beneath the Chattanooga shale.

Farther south in the Florence field (T. 21 S., R. 5 E.) production is from cherty dolomitic limestone which likewise lies directly beneath the Chattanooga shale, and has been called Viola by most geologists working in the area. But here, as was explained in a previous paper,[20] it is believed that Siluro-Devonian "Hunton" strata underlie the Chattanooga shale, and directly overlie Viola beds, with the Maquoketa formation missing. The National Refining Company's Urschel well No. 4 (SW. ¼, Sec. 16, T. 21 S., R. 5 E.) illustrates this relationship. It was completed in 1920, producing 400 barrels per day from a cherty limestone at 2,343 feet just beneath the base of the Chattanooga shale. This cherty limestone, here called Siluro-Devonian "Hunton," continues downward to 2,378 feet where there begins a 12-foot bed of sandy limestone with some pyrite, this being considered the unconformity which separates the Hunton and Viola formations. Below 2,390 feet there is a dolomitic limestone which is believed to be the lower limestone (zone 5) of the Viola, with possibly some of zone 3 also present, but with zones 1, 2, and 4 missing.

HARVEY, NORTHERN SEDGWICK, AND NORTHWESTERN BUTLER COUNTIES

Stratigraphy.—In Harvey and adjacent counties midddle Ordovician limestones are thinner and more uniform in composition than farther north. Chert is absent in samples from most wells, and the section normally is a gray or tan crystalline limestone (Fig. 23) which may be sandy near the base (Fig. 24) but otherwise is commonly rather pure. This is interpreted as the lower limestone (zone 5)

[20] Hall Taylor, *op. cit.*, p. 1251.

with a few feet of basal clastic beds (zone 6) appearing in some wells. The upper and middle members (zones 1, 2, 3, and 4) do not extend this far south. In western Harvey County the tan and brown limestone is calcitic, and shows some black or gray splotches. In eastern Harvey, northern Sedgwick, and northwestern Butler counties it is dolomitic (Fig. 23) and rather uniform brown or gray. The stippled chert of zone 6 at the north is missing, but beneath zone 5 limestones in some wells is smooth or sugary, brown, dark-specked chert, dolocastic in residues, which it is believed belongs in the Simpson sand.

In the region of the Hollow-Nikkel pool (T. 21 and 22 S., R. 3 W.), which produces from Siluro-Devonian but not Viola strata, Johnston[21] has noted a sandy layer intercalated in the Viola limestone.

It has been reported that Maquoketa-Sylvan shales thin toward the south in central Kansas, and disappear in northwestern Butler County, leaving dolomitic Siluro-Devonian Hunton strata lying directly on Viola rocks of somewhat similar appearance.[22] However, there is one difference. The Hunton contains varying amounts of tan, rough to smooth chert which is dolocastic in residues, whereas the Viola is a rather uniform brown or gray, chert-free dolomitic limestone.

A recent paper by Ver Wiebe[23] has questioned the Siluro-Devonian age of the "Hunton," and has placed the formation, together with the underlying shale called Maquoketa-Sylvan by this writer, in the "Kinderhook" of the "Mississippian sequence of central Kansas." Evidence against such a view has been presented by Carmody[24] in a recent discussion of Ver Wiebe's paper.

In a few wells near the Nemaha arch some sand and drusy quartz is mixed through the entire Viola section (Fig. 25) instead of appearing only near the base. This relationship is exceptional, but may indicate that Simpson strata locally furnished sandy material from small highs during Viola time.

Structure.—Examination of a limited number of samples indicates that Viola limestones are missing in parts of Butler County near the Nemaha arch, but the extent of these stripped areas is not completely established. Viola strata dip gently westward from the Nemaha ridge, with minor reversals appearing at the sites of the Halstead pool (T. 22 and 23 S., R. 2 W.), and the Voshell anticline (T. 22 S., R. 3 W.) in Harvey County.

Oil zones.—The oil fields of western Harvey County produce from Mississippian, Siluro-Devonian, and some Ordovician strata; but apparently no oil is produced from Viola beds. It is interesting to note that in this area the Viola, which is chiefly the lower limestone member (zone 5), is a rather pure calcitic

[21] Leslie A. Johnston, "Pre-Pennsylvanian Stratigraphy of the Hollow Pool and Adjacent Areas of the Central Kansas Basin," *Tulsa Geol. Soc. Digest* (1934), p. 12.

[22] Hall Taylor, *op. cit.*, p. 1247.

[23] W. A. Ver Wiebe, "Kinderhook Dolomite of Sedgwick County, Kansas," *Bull. Amer. Assoc. Petrol. Geol.*, Vol. 30, No. 10 (October, 1946), pp. 1747–55.

[24] R. A. Carmody, "Kinderhook Dolomite of Sedgwick County, Kansas" (Discussion), *Bull. Amer. Assoc. Petrol. Geol.*, Vol. 31, No. 1 (January, 1947), pp. 159–60.

limestone; whereas on the south and east in Sedgwick and Butler counties this zone 5 Viola member becomes oil-bearing and is largely dolomitic.

In Sedgwick County some of the oil in fields such as Eastborough, Greenwich,[25] Petrie, and Valley Center has been ascribed to the Viola. In much of this area Hunton strata lie directly on Viola beds with the Maquoketa missing, and some of the so-called Viola oil is in reality coming from the Hunton. This was recently noted by Carmody[26] in a discussion paper which states that the "Hunton dolomite, which rests directly on Viola dolomite, is the principal producing formation of the Greenwich field in Secs. 14 and 15, T. 26 S., R. 2 E."

Butler County producing zones range in age from Permian to Ordovician. The oil has commonly accumulated as the result of structural or stratigraphic traps associated with the Nemaha arch. Measured stratigraphically, truncation cuts progressively lower toward the axis of the arch, and brings nearly every pre-Pennsylvanian formation of the region into contact at some place with overlying Pennsylvanian beds.

The Siluro-Devonian Hunton limestone is believed to extend over much of Butler County just as in Marion County on the north, and it is possible that some oil, hitherto ascribed to the Viola, is actually Hunton. But in other areas the Hunton has been removed by beveling which was concomitant with rise of the Nemaha arch, and oil occurs in a dolomitic limestone, believed to be the lower limestone member (zone 5) of the Viola, which in places directly underlies Pennsylvanian strata. Such a relationship is shown in the Eldorado field by the Skelly Oil Company's Hazlett well No. 43 (SE. $\frac{1}{4}$, Sec. 19, T. 25 S., R. 5 E.) which passes at 2,475 feet from Pennsylvanian shale into dolomitic limestone which is 30 feet thick and oil-bearing in part, and is believed to be the lower limestone member (zone 5) of the Viola. Beneath this, beginning at 2,505 feet, are sands and green waxy shales of the Simpson (Fig. 10, well No. 39).

SUMMARY

A middle Ordovician limestone section, originally called Viola and now also considered approximately equivalent to the Kimmswick of Missouri, Galena of Iowa, and Fremont of Colorado, underlies Maquoketa-Sylvan shales and overlies Simpson sands and shales in the subsurface of central Kansas. Lithologically, it is divisible into six members.

At the top is the *upper limestone* (*zone 1*), a coarsely crystalline dolomitic limestone which, in part at least, appears to be a zone of dolomitization beneath the Maquoketa-Sylvan unconformity rather than a member containing beds deposited during a substage of geologic time. Below this is the *upper cherty member* (*zone 2*), with smooth microfossiliferous chert mixed in limestone which in central

[25] Arnold S. Bunte, "Subsurface Study of Greenwich Pool, Sedgwick County, Kansas," *Bull. Amer. Assoc. Petrol. Geol.*, Vol. 23, No. 5 (May, 1939), p. 649.

[26] R. A. Carmody, *op. cit.*, p. 160.

Kansas, occurs only in the north around Mitchell County. Next is the *middle limestone* (*zone 3*), a rather pure calcitic and dolomitic member which extends southward into Marion County. Below this is the *middle cherty member* (*zone 4*) which is still more extensive, and is characterized by black specks in the chert accompanying the limestone. Most widespread of all the members is the *lower limestone* (*zone 5*)which covers central Kansas except the Central Kansas uplift and a few isolated highs on the east. It is a rather pure crystalline limestone calcitic in the north and more dolomitic toward the south. Below this and at the base of the limestone section is the *lower cherty* or *basal clastic member* (*zone 6*), with chert, drusy quartz and sand mixed with limestone, indicating these are basal clastic beds of a limestone-forming sea.

The strata are more than 250 feet thick at the north in Mitchell County and, through gradual disappearance of upper portions of the section, apparently as a result of non-deposition rather than extensive truncation, thin toward the west, south, and east. They are absent from most of the Central Kansas uplift, from some parts of the Nemaha arch, and from small local areas between those structures. They dip gently into a trough, the Conway syncline, whose axis extends north and south across western Ottawa, Saline, and McPherson counties, but dips are reversed locally over folds.

Comparisons with tentative correlations by Lee and others in northeastern Kansas indicate zones 1 to 3 may be equivalent to the Stewartville (or younger), zones 4 and 5 to the Prosser, and zone 6 to the lower Prosser or Decorah of Iowa. Correlations presented in this paper are believed to indicate at least two breaks in continuity of sedimentary deposition, one above and the other below the middle cherty limestone (zone 4), and additional breaks may occur higher in the section in strata which are not extensively represented in central Kansas.

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DEVELOPMENTS IN ROCKY MOUNTAIN REGION IN 1946[1]

E. W. KRAMPERT[2]
Casper, Wyoming

ABSTRACT

The total well footage drilled in the Rocky Mountain region increased in 1946 as compared with 1945 due to the active development of the Rangely field in northwestern Colorado. Footage drilled in Wyoming and Montana in 1946 was less than that drilled in 1945.

Oil production increased in Montana, Wyoming, and Colorado in 1946 as compared with 1945. The production increase in Colorado was 235 per cent due to the rapid development in the Rangely field.

There were more discoveries in 1946 than in 1945 and several of them were of considerable importance.

INTRODUCTION

This report covers Montana, Wyoming, Colorado, Utah, Nevada, Idaho, most of North Dakota and South Dakota, and the western part of Nebraska. Statistical data from the outlying areas are admittedly incomplete and the figures on total wells and footage drilled in the more important areas are based on total wells drilled rather than on completions only.

The Rocky Mountain region had very active development during the war, reaching a maximum in number of wells drilled in 1944, which has again been surpassed in 1946. Production, as a result of increased development, increased each year during the war and showed a rather marked increase in 1946.

Footage drilled in Colorado in 1945 more than doubled that of 1944, and in 1946 again more than doubled that of 1945. This increased development is entirely due to activity in the Rangely field, which will continue through 1947. The success of the Rangely field has also stimulated drilling activity in other parts of northwestern Colorado, and adjoining parts of Utah.

It is anticipated that wildcat drilling will continue on a large scale for several years in the Rocky Mountain region as a whole.

Production in the region reached an all-time high in 1946. Montana production in 1946 increased 6% over 1945, Wyoming production in 1946 increased 7.3% over 1945, and Colorado production in 1946 increased 235% over 1945, due to increased production in the important Rangely field.

STATISTICS

Table I summarizes drilling activities in the region in 1946, with comparative figures for several previous years. Table II gives production figures in 1946 with comparative production for several previous years. Table III tabulates important discoveries in 1946.

[1] Manuscript received, May 27, 1947. Read by title before the Association at Los Angeles March 24–27, 1947.

[2] Consulting geologist.

TABLE I

A. Wells Drilled in Rocky Mountain Region in 1946

State	Successful Wildcats	Unsuccessful Wildcats	Successful Deeper-Pool Tests	Unsuccessful Deeper-Pool Tests	Successful Outpost Wells	Unsuccessful Outpost Wells	Field Wells	Total Wells Drilled	Total Feet of Hole
Montana New pool	2	8	2	3					
Wildcat discoveries	4	15			10	21	326	391	648,121
Wyoming Wildcats	5	23	4	4	5	7	210	258	701,639
Colorado	1	16	0	3	0	0	258	278	1,181,427
South Dakota	0	6	0	0	1	0	6	13	20,430
Utah	0	8	0	0	0	0	16	24	41,556
North Dakota	0	0	0	0	0	0	11	11	15,023
Nevada	0	0	0	0	0	0	0	0	0

B. Total Drilling Activity in Four States by Years

Year	Montana		Wyoming		Colorado		Utah	
	Wells	Footage	Wells	Footage	Wells	Footage	Wells	Footage
1942	265	464,858	179	483,025	55	109,125	6	11,807
1943	373	680,145	227	621,936	78	118,364	9	22,066
1944	497	1,030,544	316	961,559	94	246,165	9	7,535
1945	412	795,858	320	987,473	134	512,246	17	21,582
1946	391	648,121	258	791,639	278	1,181,427	24	41,556

TABLE II

Oil Production in Barrels

State	1943	1944	1945	1946	Cumulative
Montana	7,892,205	8,623,264	8,364,090	8,864,458	130,993,060
Wyoming	34,230,711	33,245,333	36,421,158	39,099,929	709,980,589
Colorado	2,363,335	3,075,090	5,030,063	11,828,306	67,339,540
Utah	15,150[a]	21,557[a]	20,105[a]	20,000[b]	371,786
Total	44,501,410	44,965,244	49,835,416	59,812,693	908,684,975

[a] Distillate from Clay Basin gas field.
[b] Same estimated for 1946.

DISCOVERIES

Discoveries in the Rocky Mountain region in 1946 total 19. Ten of these are classified as new fields, 6 are classified as new pools and 2 are classified as deeper pools according to Lahee's classification. One gas area in Montana omitted from Lahee's paper has been inserted here as an outpost discovery.

COLORADO

Elk Springs.—The Elk Springs field is on a small closure on the eastward extension of the Skull Creek anticline north of the Rangely anticline. The Continental Oil Company completed an oil well in the Weber sand at the total depth of 6,231 feet on this structure in Sec. 30, T. 5 N., R. 98 W., Moffat County, on November 27, 1946.

The well does not indicate an important discovery, but it is the first producing well from the Weber sand in Colorado outside of the important Rangely field.

TABLE III

1946 Discoveries in Rocky Mountain Region

State	Operator	Name of Well	County	Location S-T-R	Completion Date	Total Depth (Feet)	Sand Depth (Feet)	Name of Discovery Zone	Name of Field	Initial Production (Barrels per Day)	Type of Discovery
Colorado	Continental	Smith 1	Moffat	30-5N-98W	11/27/46	6,231		Weber	Elk Springs		New field
Montana	Hanlon	Gov't. 1	Garfield	6-14N-31E	3/3/46	1,821		Ellis	E. Mosby	125	New field
	Union Oil Company	Stufft 1	Glacier	19-36N-5E	5/5/46	3,097		Madison	Headlight Butte Nose	114	New field
	Schwartz	Gov't. 1	Petroleum	22-13N-28E	6/18/46	3,235		2d Cat Creek	Rattlesnake Butte	20	New field
	A.A. Oil Company	Parsell 1A	Toole	4-36N-3E	8/1/46	2,036		Sd. in Colo. sh.	Apex	3,000 MCF	New field
	Texas Company	Laas 2	Liberty	14-33N-4E	9/26/46	4,593	3,775	Jefferson	E. Utopia	20,000 MCF	New pool
	Montana-Dakota Utilities	Radabaugh 286	Toole	19-33N-2E	2/19/46	745	745	Colorado sh.	Devon	3,000 MCF	New pool
	Chamberlin	Rhens 12	Petroleum	9-15N-29E	3/11/46	1,760	1,397	Morrison	W. Cat Creek	20	Deeper pool
	Continental	Harlen 11	Petroleum	10-15N-29E	6/7/46	1,904	1,904	Ellis	W. Cat Creek	23	Deeper pool
	E. H. Becker		Fallon	28-5N-60E		1,053	1,050	Judith River	Baker-Glendive	250 MCFG	Outpost
Wyoming	Sinclair-Wyoming	Dubois U-1	Fremont	11-42N-101W	2/27/46	3,571	2,155	Phosphoria	Dubois	150	New field
	Continental	Van Noy 1	Hot Springs	3-43N-93W	6/12/46	4,139	4,139	Phosphoria	Corley		New field
	Texas Company	Unit 1	Sweetwater	1-18N-98W	4/14/46	3,831	3,334	Lance	Table Rock		New field
	Mountain Fuel Supply	Unit 1	Uinta	8-16N-112W	6/21/46	12,894	12,666	Dakota	Church Buttes		New field
	Morton & Siegal	State 1	Weston	16-44N-62W	5/1/46	3,414	3,365	Newcastle	Mush Creek		New field
	Continental	Shoshone 4	Fremont	6-6N-2W	11/19/46	1,947		Madison	Circle Ridge	120	New pool
	Texas Company	State 3	Hot Springs	36-43N-91W	7/30/46	2,980		Madison	Black Mountain	161 oil, 77W	New pool
	Stanolind (Unit Operator)	Unit 38M	Park	24-58N-100W	12/14/46	5,300		Madison	Elk Basin	240 SI	New pool
	Superior Oil of Calif.	Wyoming Pet. 1	Sublette	34-30N-113W	11/1/46			Wasatch	Big Dry Piney	700 MCFG	New pool

MONTANA

East Mosby.—Oil was discovered on March 3, 1946, in Sec. 6, T. 14 N., R. 31 E., by Wm. Hanlon in the Ellis sand. This discovery is on the most easterly dome of the Cat Creek anticline which has not previously produced from other sands. Oil was discovered on another dome of the Cat Creek anticline in the Ellis sand in 1944. Oil has been produced from the Cat Creek sands of the Kootenai formation on the Cat Creek anticline since 1920.

The East Mosby field appears to be a rather important small pool and is now producing from both the Brindley and Ellis sands, which are closely related, both being of Jurassic age and underlying the Kootenai formations.

Headlight Butte Nose.—The Union Oil Company made a discovery of oil in the Madison limestone on Headlight Butte Nose on May 5, 1946. The well is in Sec. 19, T. 36 N., R. 5 W., Glacier County, Montana. This area is usually classified as a part of the Cutbank field, but the Union discovery has been classified as a new field rather than an outpost. The Carter Oil Company in 1945 made the first discovery of commercial oil in the Madison limestone in the Cutbank area.

Rattlesnake Butte.—H. H. Schwartz completed a well in Sec. 22, T. 13 N., R. 28 E., Petroleum County on June 18, 1946, producing 20 barrels per day. This well is on a faulted dome about 12 miles southwest of the West Cat Creek field. The oil occurred in the Second Cat Creek sand. Several previous wells on the same structure had encountered showings of oil.

Apex structure.—Commercial gas was discovered in a well drilled by the A. A. Oil Company, in Sec. 4, T. 36 N., R. 3 E., Toole County, completed August 1, 1946, producing 3 million cubic feet daily initially. The producing zone is a sand in the Blackleaf sandy member of the Colorado shale.

This new field is on the Sweetgrass arch east of the Kevin-Sunburst field

East Utopia.—The Texas Company made an important discovery of gas in a well drilled in Sec. 14, T. 33 N., R. 4 E., Liberty County, completed producing 20 million cubic feet per day from the Jefferson limestone of Devonian age.

Gas and oil had previously been discovered in the Utopia field from upper beds. This discovery is important in proving commercial production in the Devonian formation, which will probably be tested in many future wells in the general area east of the Sweetgrass arch.

Devon field.—Gas was discovered in a sand in the Blackleaf member of the Colorado shale in the Devon area on the Sweetgrass arch east of the Kevin-Sunburst field. The discovery well was drilled by the Montana-Dakota Utilities Company in Sec. 19, T. 33 N., R. 2 E., and completed February 19, 1946, producing 3 million cubic feet per day.

West Cat Creek.—Two wells listed in Table III as Rhens No. 12 and Harlan No. 11 are listed as new-pool discoveries in 1946. The new sands are the Morrison and Ellis, closely related sand of Jurassic age underlying the Kootenai formation. The Cat Creek sands of the Kootenai formation have yielded oil in this field since

1920. Oil was discovered in the Morrison and Ellis formations on another dome on the Cat Creek anticline in 1944.

West Baker Glendive.—E. H. Becker drilled five small producing gas wells in T. 5 N., R. 60 E., in Fallon County, in 1946. These wells are located close to, but across the syncline from, the Baker Glendive anticline, which has produced gas from the same sand for many years.

The wells are shallow and small producers and are not listed in Lahee's report.

WYOMING

Dubois.—Sinclair Wyoming completed an oil well producing from the Phosphoria member of the Embar formation of Permian age on the Dubois structure on February 27, 1946. The well is in Sec. 11, T. 42 N., R. 101 W., Fremont County, and is the most westerly production found to date in the Wind River basin area.

The oil is asphaltic base of low gravity and the well does not indicate a field of much importance.

Corley dome.—The Continental Oil Company completed the discovery well on the Corley dome in Sec. 3, T. 43 N., R. 93 W., Hot Springs County, on June 12, 1946. Several additional wells were drilled before the end of the year.

Development indicates a small pool productive from the Phosphoria member of the Embar formation at an average depth of 4,100 feet.

Table Rock.—The Texas Company completed a small gas well at the top of the Lance formation of uppermost Cretaceous age on the Table Rock structure in Sec. 1, T. 18 N., R. 98 W., Sweetwater County, on April 14, 1946, at 3,831 feet.

The Table Rock field is in the Red Desert Basin east of the Rock Springs uplift. The discovery is of little importance except to indicate closure on a structure located in a deep structural basin.

Church Buttes.—The first Church Buttes well was listed as completed on June 21, 1946, although drilled to its total depth in the previous year. The discovery well was drilled by Mountain Fuel Supply Company in Sec. 8, T. 16 N., R. 112 W., Uinta County, and at the time of its completion was the deepest well in Wyoming (12,894 feet).

Two subsequent wells indicate a large productive area on a deep-seated low dome in a deep structural basin (Green River Basin) west of the Rock Springs uplift. The productive zone is the Dakota group of sands containing wet gas and distillate under very high pressure.

The discovery is of special importance as an indication of the possibilities of production at depths below 10,000 feet in the deep structural basins of the Rocky Mountain region.

Mush Creek.—A new discovery is reported in the Mush Creek area of Weston County, Wyoming. This well was drilled by Morton and Siegel in Sec. 16, T. 44 N., R. 62 W. Oil was found in the Newcastle sand at 3,365 feet.

At least one well has been previously reported as a discovery well in the Mush Creek area but it was several miles farther west.

The Mush Creek area is a homocline dipping about 175 feet per mile off the southwest flank of the Black Hills uplift. The producing formation is the Newcastle sand, which has a rather consistent thickness of about 60 feet as a zone, but contains lenticular porous sands.

The lenticular porosity is capable of trapping oil and gas in the homoclinal structure. Conditions in this area are similar to those in the Osage field several miles farther north.

Circle Ridge.—The Continental Oil Company completed a deep test on Circle Ridge dome to the Madison limestone on November 19, 1946 at the total depth of 1,947 feet. The discovery well produced 120 barrels per day from the new zone. The field is in T. 6 N., R. 2 W., Fremont County, and produces similar oil from the Embar and Tensleep formations.

Black Mountain.—The Texas Company completed a deep test on the Black Mountain anticline to the Madison limestone on July 30, 1946, at the total depth of 2,980 feet. The discovery well produced 160 barrels of oil and 77 barrels of water per day from the new zone. The field is in T. 43 N., R. 91 W., Hot Springs County, in the southern part of the Big Horn Basin and produces similar oil from the Embar and Tensleep formations.

Elk Basin.—The Stanolind Oil and Gas Company as unit operator completed a producing Madison limestone well in the Elk Basin field on December 14, 1946, at 5,300 feet. The producing section is indicated as being several hundred feet thick. The discovery well, perforated into the lower part of the saturated section, yielded 240 barrels per day of 28° gravity oil similar to the oil produced from the Tensleep sand.

Big Dry Piney.—A new gas pool is reported in the Big Dry Piney field in Sublette County, Wyoming. The discovery is the Superior Oil Company's well in Sec. 34, T. 30 N., R. 113 W. Gas is produced from a sand in the Eocene Wasatch formation.

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GEOLOGICAL NOTES

GEOSYNCLINAL NOMENCLATURE AND THE CRATON[1]

MARSHALL KAY[2]
New York, New York

INTRODUCTION

Geosynclines are the largest stratigraphic units, comprising rocks of relatively great thickness and extent laid in sinking areas in the earth's surface. Classification is based on the rocks, rather than on the form of the original surface of deposition, or on subsequent tectonic or vulcanic history. Some have referred to oceanographic "troughs" and structural synclinoria as geosynclines. Though the etymology of the word, earth down-fold, does not exclude them, the original definition[3] gives rocks as representatives, considers geosynclines to be potential sites of orogeny though including unfolded examples, and definitely excludes synclinoria.

CRATON

North America had a comparatively stable interior in the early Paleozoic, bordered by more mobile geosynclinal belts. A consolidated, rather immobile area such as this central shield is a *craton*[4] (krā'-tŏn)[5], the adjoining geosynclines are *orthogeosynclines*[6] (that is, straight), geosynclines lying between cratons, whether higher continental or lower oceanic cratons. The monoclinal flexure or hinge delimiting the North American early Paleozoic craton trended on present geography from Labrador toward Quebec City, thence through northeastern New York, south-central Pennsylvania, northwestern Virginia, and eastern Tennessee, to central Alabama; the medial Ordovician position is the Adirondack line (Fig. 1).[7] That on the west, along the Wasatch line,[8] extended from western Mackenzie through western Alberta, Montana, and Wyoming to central Utah, southeastern

[1] Manuscript received, March 8, 1947.

[2] Professor of geology, Columbia University. Suggestions of Professor W. H. Bucher are particularly appreciated.

[3] J. D. Dana, "On Some Results of the Earth's Contraction from Cooling Including a Discussion of the Origin of Mountains and the Nature of the Earth's Interior," *Amer. Jour. Sci.*, 3d Ser., Vol. 5 (1873), p. 430.

[4] Hans Stille, "Wege und Ergebnisse der geologisch-tektonischen Forschung," *25 Jahre Kaiser Wilhelm Gesellsch. Förd. Wissensch.*, Bd. 2 (1936), pp. 84–85.

[5] Pluton and allochthon have similarly pronounced endings.

[6] Hans Stille, *op. cit.* (1936).

[7] Marshall Kay, "Development of the Northern Allegheny Synclinorium and Adjoining Regions," *Bull. Geol. Soc. America*, Vol. 53 (1942), p. 1748.

[8] Hans Stille, *Einführung in den Bau Amerikas*, Borntraeger, Berlin, 1940 (1941), p. 83.

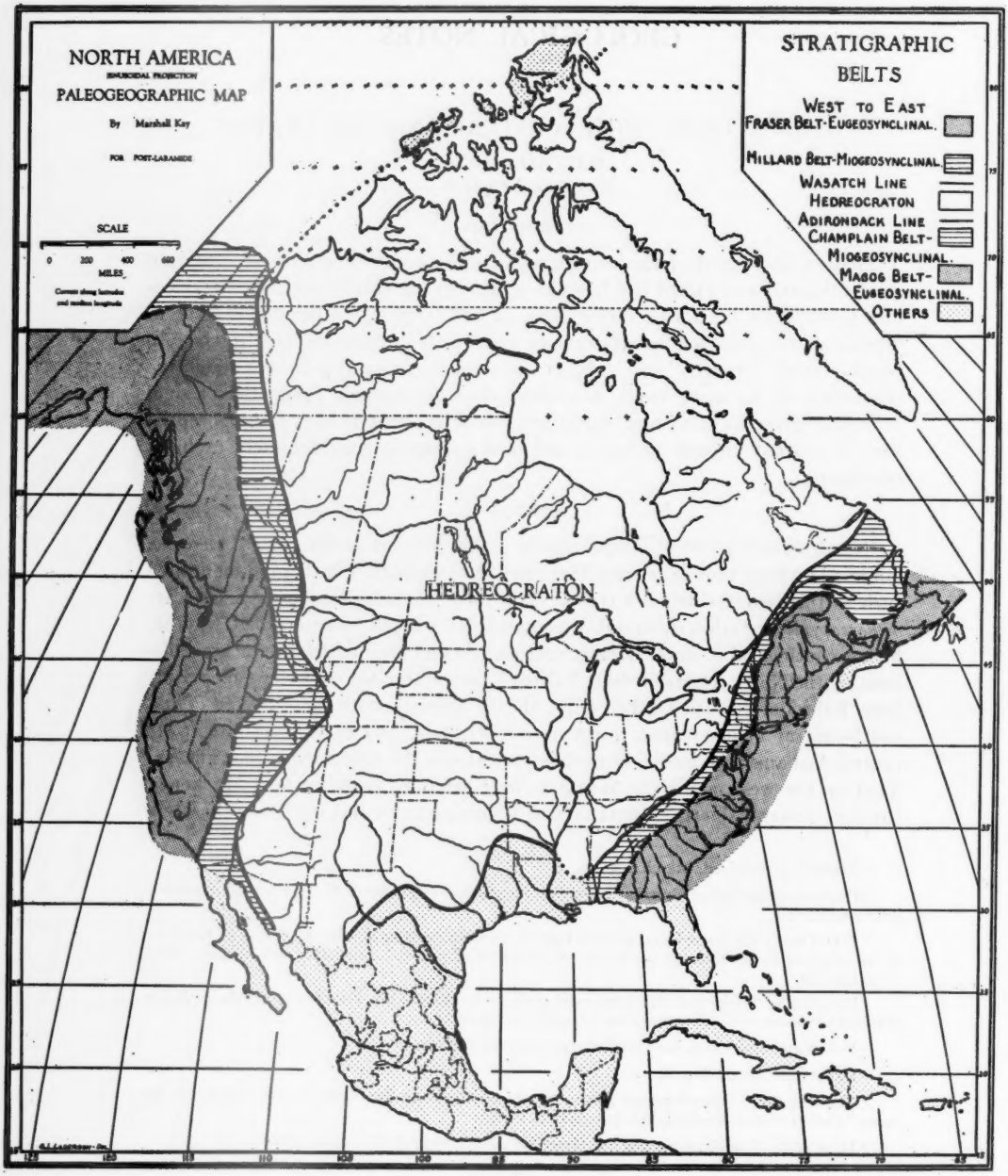
NORTH AMERICA
PALEOGEOGRAPHIC MAP
By Marshall Kay
FOR POST-LARAMIDE
SCALE
0 200 400 600
MILES
STRATIGRAPHIC
BELTS
WEST TO EAST
FRASER BELT-EUGEOSYNCLINAL.
MILLARD BELT-MIOGEOSYNCLINAL.
WASATCH LINE
HEDREOCRATON
ADIRONDACK LINE
CHAMPLAIN BELT-
MIOGEOSYNCLINAL.
MAGOG BELT-
EUGEOSYNCLINAL.
OTHERS
HEDREOCRATON

FIG. 1

Nevada, and western Sonora. A craton is transitory, expanding as orogenies add rocks of former orthogeosynclines, contracting as new orthogeosynclines reduce its area.

North America is perhaps peculiar in that the early Paleozoic craton has had persisting influence on continental development, and has close correlation with present structure. Although the eastern side lost the initial bordering geosyncline by the middle Paleozoic, the western flexure endured into late Mesozoic. The area of this early Paleozoic North American craton is designated as an *hedreocraton* (steadfast),[9] one having long continuing influence.

ORTHOGEOSYNCLINES

The classification of geosynclines is based on their form, the character and derivation of their rocks, and in the principal classes, on their position relative to a craton. The linear orthogeosynclines between cratons are of two types, *miogeosynclines* (less) and *eugeosynclines* (truly).[10] Those nearer the craton, the miogeosynclines, were rather regularly sinking as deposition progressed and lack appreciable volcanic material; North American early Paleozoic miogeosynclines derived their initial detritus from erosion of the hedreocraton. The more distant eugeosynclinal belts had rapidly sinking linear geosynclines with locally thick and abundant volcanic rocks, as well as sediment eroded from rising narrow intervening lands, like island arcs. The early Paleozoic rocks in the eastern eugeosynclinal belt of North America extend from central Newfoundland throughNew Brunswick, Maine, New Hampshire, and central Massachusetts to the Atlantic Piedmont; possibly eastern Newfoundland and Nova Scotia lie in an opposite miogeosynclinal belt. Devonian orogeny with accompanying intrusion closed the eugeosynclinal history. Paleozoic and early Mesozoic rocks in the western eugeosynclinal belt extend westward to the Pacific from central Alaska, Yukon and British Columbia, western Idaho and central Nevada, occupying all but southeastern California; eugeosynclinal development ended with the late Jurassic Nevadian orogeny.

The present areas of the early Paleozoic eastern miogeosynclinal and eugeosynclinal rocks have been called the Champlain and Magog belts.[11] It is proposed that the corresponding western belts of miogeosynclinal and eugeosynclinal rocks be called the Millard and Fraser belts, after Millard County, Utah and Fraser River, British Columbia. The Millard belt had exceptionally broad and long

[9] Pre-Paleozoic cratons had quite different disposition; thus the pre-Algoman rocks north of Lake Superior and east to western Quebec formed in an orthogeosynclinal belt (F. J. Pettijohn, "Archean Sedimentation," *Bull. Geol. Soc. America*, Vol. 54 (1943), p. 968); and the late pre-Cambrian Beltian sediments of the west (N. E. A. Hinds, "Uncompahgran and Beltian Deposits in Western North America," *Carnegie Inst. Washington Pub. 463* (1936), pp. 53–136) formed in a great geosyncline extending far into the hedreocraton.

[10] Hans Stille, *op. cit.* (1941), p. 15.

[11] Marshall Kay, "Stratigraphy of the Trenton Group," *Bull. Geol. Soc. America*, Vol. 48 (1937), p. 290.

continuing miogeosynclinal development in Paleozoic and earlier Mesozoic, submarine volcanic rocks being almost absent; it is not now a miogeosyncline, and the rocks were so distorted by post-miogeosynclinal orogenies as to require restoration to their original relative geographic positions on palinspastic base maps[12] to give true paleogeography. The eastern margin has major Laramian[13] thrusts, and plutons are present in limited areas. The Fraser belt contains rocks of Paleozoic and earlier Mesozoic eugeosynclines and intervening narrow lands; the rocks in the belt are of types characteristic of eugeosynclines interruptedly in place and time. It contains the principal late Jurassic Nevadian plutons, and its eastern margin is a zone of major thrusts.

GEOSYNCLINES WITHIN CRATONS

Three types of geosynclines lie outside the orthogeosynclines and within the cratons. A geosyncline invading the margin of a craton, having detritus gained principally from orogenic highlands in the adjacent belts of orthogeosynclinal rocks, was called by the writer a deltageosyncline.[14] The term was ill chosen and confusing, for it has been supposed to include deposits in various stream deltas. Therefore, it is proposed that *exogeosyncline* (outside) replace the term deltageosyncline, in reference to the principal source of detritus being outside the craton; the Upper Ordovician, earlier Silurian, and later Devonian of Pennsylvania and adjacent states are typical; stratigraphic units commonly diverge until they closely approach the source. The second type, the *autogeosyncline*[15] has in the typical Upper Silurian and Devonian of lower Michigan, non-detrital carbonates and salines, and detritus from low near-by land and from orogenic mountains in a distant orthogeosynclinal belt; stratigraphic units generally converge gradually from the center or axis of the deposit. Autogeosynclines may trend toward orthogeosynclinal belts, but seem essentially independent of them; the structure of the base changed from a plane to a basin or trough as the geosyncline developed. An exogeosyncline tends to diminish gradually and regularly within the craton or to pass into autogeosynclinal patterns, as in the earlier Upper Cretaceous of the western hedreocraton, whereas a miogeosyncline tends to meet the craton in a distinct flexure. American Paleozoic and Mesozoic exogeosynclines enter the margin of the hedreocraton. A third type, the *zeugogeosyncline*[16] (yoked), has detritus from near-by uplifts within the craton, as in the late Paleozoic of northwestern Colorado.

[12] Marshall Kay, "Paleogeographic and Palinspastic Maps," *Bull. Amer. Assoc. Petrol. Geol.*, Vol. 29 (1945), pp. 426–50.

[13] Structures formed in the Laramian orogeny are Laramides: *ibid.*, pp. 447–49.

[14] Marshall Kay, "Development of the Northern Allegheny Synclinorium and Adjoining Regions," *Bull. Geol. Soc. America*, Vol. 53 (1942), p. 1643.

[15] Marshall Kay, *ibid.*

[16] Marshall Kay, "North American Geosynclines—Their Classification" (abstract), *Bull. Geol. Soc. America*, Vol. 56 (1945), p. 1172.

OTHER GEOSYNCLINES

There are other geosynclinal types whose definition does not depend on their relations to the hedreocraton. A *taphrogeosyncline*[17] (trench) is bounded by high-angle faults, as in the late Triassic geosynclines of the Atlantic Coast. An *epieugeosyncline*[18] (above) has elongate, relatively non-volcanic deposits derived from adjoining rising swells in areas of former eugeosynclines, as in the Carboniferous of Nova Scotia, and the Tertiary of California. The *idiogeosyncline*[19] (distinct), based on the Tertiary of central Sumatra and Java, has not been defined on a comparable basis, but suggests a late-cycle miogeosyncline. A *paraliageosyncline*[20] (coastal) is one such as the Tertiary of the northern Gulf of Mexico coast, a linear geosyncline along the present continental margin, having flexures on the foreland similar to those delimiting miogeosynclines.

GEOSYNCLINAL DURATION

Geosynclines have temporal as well as geographic limits. Deformation in a single cycle commonly but not invariably progresses from orogenies in the eugeosynclinal belts to those in the miogeosynclinal belts, with development of exogeosynclines on the cratonal border, and consolidation in an enlarged craton. Subsequent cycles may have quite different positions and trends. Thus, there are belts of pre-Cambrian eugeosynclinal rocks that trend across the early Paleozoic cratons of North America and Fennoscandia. Moreover, eugeosynclines can overlie miogeosynclines, and there are instances of eugeosynclines that closely approach a craton. Though many geosynclines have the characters of a single class others are compound in their attributes. The late Upper Cretaceous of the western part of the North American hedreocraton is principally exogeosynclinal, but has independently sinking autogeosynclinal areas, and others of zeugeosynclinal nature adjoining rising swells in the earlier exogeosynclinal belt.

[17] Marshall Kay, "Geosynclines in Continental Development," *Science*, Vol. 99 (1943), p. 462.

[18] Marshall Kay, *op. cit.* (1945), p. 1172.

[19] J. M. B. Umbgrove, "Verschillende typen van tertiaire geosynclinalen in den Indischen Archipel," *Leidsche Meded.*, Vol. 6 (1933), pp. 33–43.

[20] Marshall Kay, *op. cit.* (1945), p. 1172.

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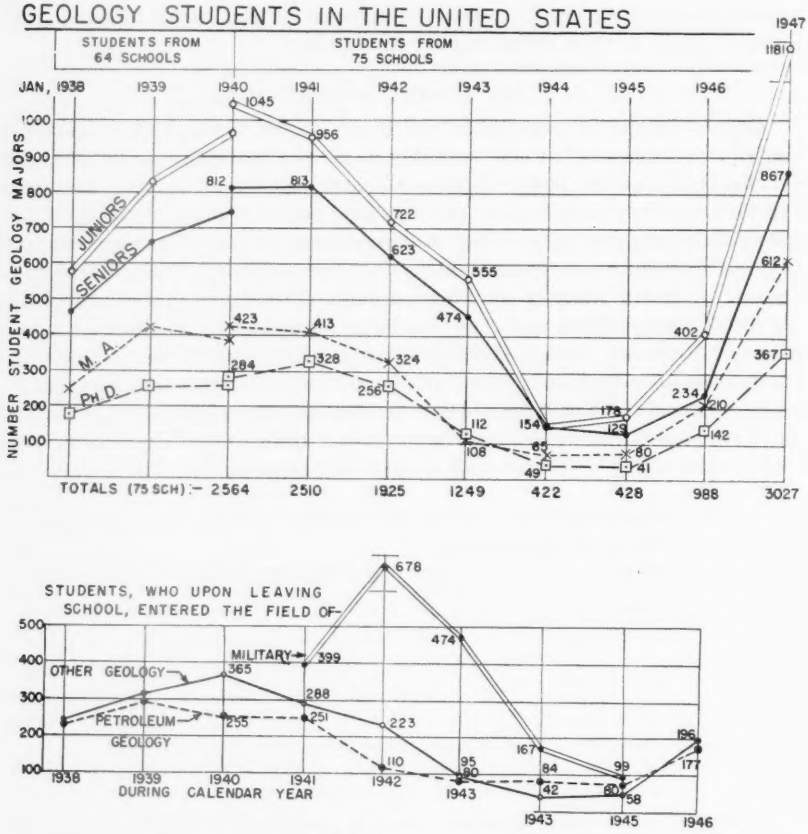
RESEARCH

SURVEY OF COLLEGE STUDENTS MAJORING IN GEOLOGY

A. I. LEVORSEN
Stanford University, California

The chart is a continuation of the surveys of recent years. It shows the trend in the number of college students majoring in geology in the United States and the placement of those leaving school during the calendar year, 1946. The latest figures are for January,



1947. In considering the chart, it should be remembered that the figures as of January, 1947, include only the enrollment in the first semester of those colleges using the two-semester systems, and the enrollment for the second quarter of those colleges using the quarter system.

SALT-DOME STRUCTURE[1]

(PRELIMINARY NOTICE)

ROBERT BALK[2]
South Hadley, Massachusetts

At the invitation of the research committee of the American Association of Petroleum Geologists, the writer had an opportunity, in August, 1946, of making a brief inspection of the salt mines in the Hockley, Grand Saline (Texas), Winnfield, Jefferson Island, and Weeks Island (Louisiana) salt domes. The purpose of the visit was to examine the feasibility and desirability of a structural investigation of some salt domes. This note describes some of the structural features seen and points out some related geological problems.

Megascopic structure.—The salt in all five mines shows a layered structure of white and gray salt. White salt is almost pure halite; gray salt contains a small proportion of anhydrite and, rarely, a few additional compounds. Salt layers vary in thickness from a fraction of an inch to several feet; white salt seems far to exceed the amount of gray salt. Layer boundaries, sharp from the distance, are elusive in hand specimens, and salt crystals, about $\frac{1}{4}$ cubic inch in size, may grow across layer boundaries. Most grains seem to be equant, and the texture of the salt is compact, but in a few places distorted halite crystals were seen in crude alignment, resembling the structure of coarse-grained gneisses.

Folds.—On vertical walls of the mines, salt layers stand in nearly vertical position. Dip angles as low as 45° were noted in places, but seem to be the exception rather than the rule. In sharp contrast with this rather monotonous succession of steep salt layers on the walls is the salt structure in the ceilings. Here a remarkable array of folds is exposed in cross section. Their axes are nearly vertical so that the observer looks nearly parallel with them, and the horizontal ceilings are cross sections of the folds. Large folds must be traced through contiguous tunnels and rooms, but under favorable conditions they can be followed for hundreds of feet. Smaller folds are completely exposed within individual room ceilings (Fig. 1). There are open folds as well as isoclinal folds. Many limbs carry smaller secondary, and even ternary, folds, and tightly appressed shear folds are common among these. How far individual folds can be traced will depend on the orientation of the mine tunnels and also on the persistence of salt layers. As in folded marbles, dark salt layers tend to lens out, and may be lost even where ceiling exposures continue.

Looking up at places where several groups of limbs have been kneaded into

[1] Manuscript received, March 15, 1947.

[2] Mount Holyoke College. It is a pleasure to acknowledge the helpful cooperation of S. W. Lowman, M. K. Hubbert, and Paul Weaver. I am under special obligation to Marcus A. Hanna for the opportunity of discussing many salt-dome problems, and permission to use his office while in Houston; he very kindly arranged the itinerary of my trip, and while *en route*. I benefited from the rich experience and advice of several other geologists of the Gulf Oil Corporation. Thanks are likewise due the managers and foremen of the various salt mines who gave generous information on each salt dome, and provided me with mine plans.

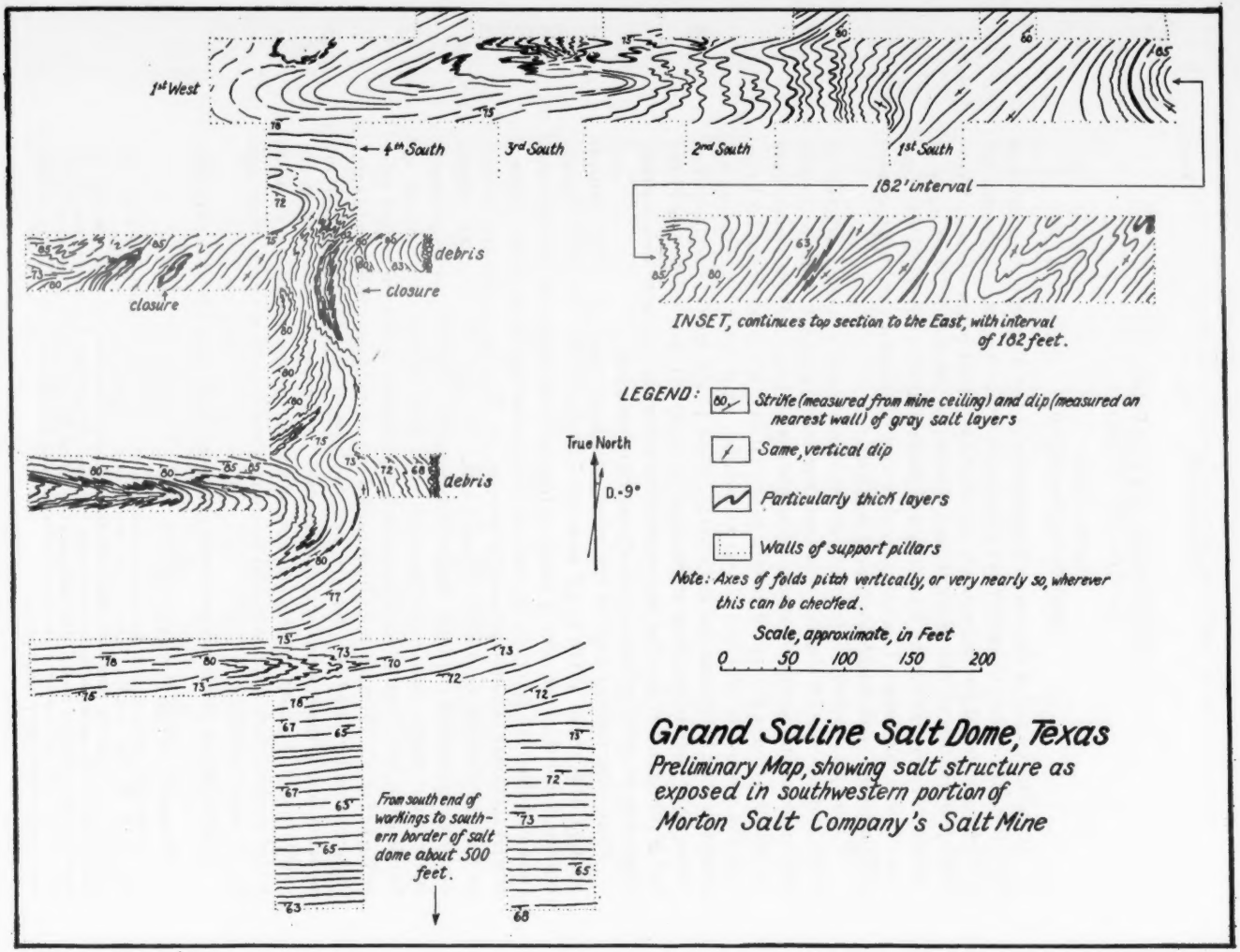

1st West
4th South
3rd South
2nd South
1st South
182' interval
debris
closure
closure
debris
INSET, continues top section to the East, with interval of 182 feet.
LEGEND:
Strike (measured from mine ceiling) and dip (measured on nearest wall) of gray salt layers
Same, vertical dip
Particularly thick layers
Walls of support pillars
Note: Axes of folds pitch vertically, or very nearly so, wherever this can be checked.
True North
D.-9°
Scale, approximate, in Feet
0 50 100 150 200
From south end of workings to southern border of salt dome about 500 feet.
Grand Saline Salt Dome, Texas
Preliminary Map, showing salt structure as exposed in southwestern portion of Morton Salt Company's Salt Mine

FIG. 1

each other (Fig. 2), one can not fail being impressed by the immensity of deformation which the salt has fixed by its fold structure.

Closures.—Closures of folds are seen in places (Fig. 2). Complete circular, elliptical, or sigmoidal traces of one and the same layer can mean only that within the large salt dome there are smaller ones. Are they found near the top of a dome only? Or can they be expected at lower levels as well? Fortunately, in one mine there are two levels, and it may be possible there to measure the rate of vertical upward tapering of closed folds. Plastic flow of the salt is evidenced by the fact that layers adjacent to closure do not indefinitely conform to this fold center, but a certain layer breaks away from it, and continues in a new direction as part of another fold.

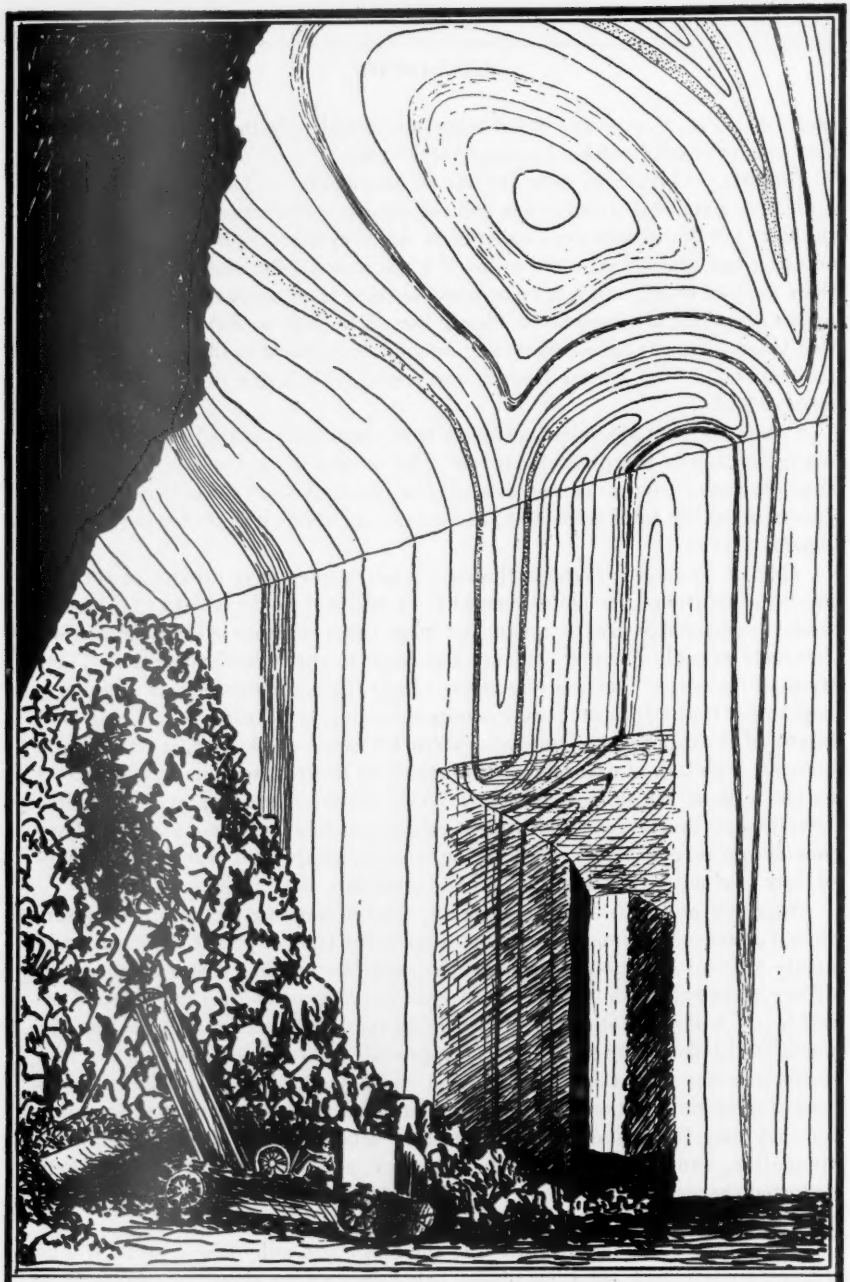
Coarse salt.—At Winnfield, and elsewhere, the miners pointed out a few places where the salt is exceptionally coarse. The miners know these places well for large, flawless cleavages can occasionally be obtained there for optical purposes. Judged from the brief inspection, the coarse salt forms irregular masses, and is generally white.

Lack of fractures.—Perhaps the coarse salt masses have developed through precipitation from brine under somewhat exceptional conditions. In that case, it would be reasonable to expect, here and there, other evidence of brine circulation. Strangely enough, no such evidence has come to the writer's attention. There seem to be neither cross-cutting layers of salt, from the existence of which one might infer that salt crystals were precipatited along a fracture, nor a single joint in any of the exposed salt surfaces, except for minor cracks due, it was said, to blasting. This lack of natural fractures stands in contrast with impressive cracks on the walls of the support pillars at Weeks Island, caused by heavy blasting. Despite their magnitude and incipient gaping, the miners are not alarmed. They pointed out several places where the outward-bulging plates crumble into heaps of loose granules rather than spall off and crash into the tunnels.

Suggested problems.—Unquestionably, careful mapping of the salt structure should advance our knowledge of the remarkable type of plastic deformation in nearly vertical directions. Although the general columnar shape of most salt domes seems well established, we lack as yet information on the orientation of the salt layers within the domes,—obviously an important matter. Should there be prevailing strikes of the layers in an appreciable part of the cross section of a dome, one may infer that the dome as a whole has a direction of elongation in plan. The origin, location, and shape of coarse salt masses deserve close attention for they may throw some light on the time relationship of deformation, brine circulation, and crystal growth. In one mine, salt crystals exhibit commonly distorted shapes and translation "steps" on cleavage faces, which may also yield some clues to the mechanics of deformation.

The crystallographic orientation of the halite and anhydrite crystals will be difficult to determine. In a few places, halite crystals are elongated in directions parallel with fold axes. The same was noted, at Winnfield, for pencil-shaped

FIG. 1



Salt Structure in the Salt Dome of Jefferson Island, Louisiana, Loc. F5

FIG. 2

aggregates of anhydrite. Where anhydrite crystals are sufficiently numerous, it may be possible to prepare oriented thin sections. Anhydrite crystals collected from insoluble residue at Jefferson Island are stubby prisms, with characteristically pitted basal terminations. The orientation of these prisms within the salt is unknown.

Once the salt structure will have been mapped in detail, a number of related geological problems are likely to emerge. Possibly, local zones of overhang are reflected in systematic, one-sided dip of contiguous salt layers. Variations in the pitch angles and azimuths of fold elements may likewise have their bearing on the orientation of salt-dome flanks. The rather active circulation of brine and gas in one dome raises special questions.

The person mapping the salt will probably need information from oil geologists and sulphur-mining companies concerning drilling and well data, thermal, gravity, and ground-water conditions in the vicinity of the dome borders. None of the salt mines actually reaches the dome borders, and only an exchange of such information should be able to integrate all available facts from which the story of the growth of these remarkable domes may be pieced together.

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DISCUSSION

DISTRIBUTION OF OCEANS AND CONTINENTS[1]

CHESTER R. LONGWELL[2]
New Haven, Connecticut

The origin and history of continental masses and ocean basins are matters of large concern to students of the Earth, who will give attention to W. G. Woolnough's recent excursion into this fascinating but speculative field.[3] Even though such discussions can lead to no positive conclusions, they stimulate us to re-examine our globes and our major geologic concepts.

Woolnough presents once more the tetrahedral hypothesis, which in his view has not received from geologists the attention it merits. He suggests that imperfect development of the tetrahedral form resulted in large part from an accident in an early stage of the Earth's history, evidenced by the great "wound" of the Pacific basin. A further thesis of his paper is that forces acting to adjust the malformed tetrahedron have caused continental drift, with particularly large displacements of Australia, India, and South America. Continued adjustments toward the tetrahedral form have been responsible for recurrent ("periodic") orogenic deformation. Thus Woolnough regards the tetrahedral concept as the most promising key to an understanding of the Earth's major topographic and tectonic features—excepting the Pacific "wound," which requires a special explanation.

TETRAHEDRAL HYPOTHESIS

In explaining the sphere as the figure with minimum surface for a given volume, the author does not specifically mention gravity as the force dictating the nearly spherical form of the Earth. He does recognize the importance of strength in a spherical shell which, in adjusting to a shrinking interior, may tend to assume the form of a tetrahedron, the figure possessing minimum volume for a given surface. The theoretical reason for such a tendency seems clear enough. A strong outer spherical shell will resist a force striving to decrease its dimensions, and will tend to assume a form, consistent with smaller volume, which permits the smallest loss in area. Although it may be possible to demonstrate such a tendency in a small-scale experiment, by arbitrary choice of a shell with suitable thickness and strength, we should not ignore critical elements in the problem in any attempt to reason from the toy model to a body with the magnitude and the gravitational force of the Earth. If the assumed tetrahedral quoins, dihedral angles, and depressed faces were actually initiated in the Earth, they could be maintained only by virtue of strength in the crust sufficient to carry indefinitely the large and persistent stresses due to gravity. Geologic and physical studies tell us that rocks composing the Earth's crust are weak as measured on a scale of geologic space and time.[4] This consideration alone places the concept under serious suspicion. However, there are other important aspects of the matter.

Readers may well question the supposed role of the Pacific "wound" in causing the extreme distortion of the original tetrahedron postulated by Woolnough. Although he does

[1] Discussion received, February 15, 1947.

[2] Department of geology, Yale University.

[3] *Bull. Amer. Assoc. Petrol. Geol.*, Vol. 30, No. 12 (December, 1946), pp. 1981–2012.

[4] See, for example, M. King Hubbert, "Strength of the Earth," *Bull. Amer. Assoc. Petrol. Geol.*, Vol. 29, No. 11 (November, 1945), pp. 1630–53.

not state a mechanical reason for such distortion, presumably he thinks of the "wound" as an area of weakness in the crust. But if fully one half of a spherical shell were unable to bear its share of the stress, surely there is no possibility that any approach to the tetrahedral figure could be made or maintained. Comparison with an apple injured during its growth has no validity for a geometric figure whose very existence depends on the ability of all its parts to endure critical stresses.

Woolnough prefaces his discussion with a list of 14 "objective facts" which must be considered in any genetic theory relating to the form and structure of the Earth. Strangely, there is in this list no mention of what we know about gravitational control in determining the form, a subject to which geodesists and geologists have given particular attention during the past half-century. The following conclusions rest on large accumulations of quantitative data won by geologic and geophysical research.

1. Continental masses are composed predominantly of siliceous rock (*sial*) extending to an average depth of tens of kilometers. Under ocean basins the sial extends to small depth or is absent, and mafic rock (*sima*) is predominant.

2. Major segments of the Earth's crust are in closely approximate isostatic balance.

These conclusions appear fatal to the tetrahedral hypothesis. If the continents exist as the surfaces of low-density plates in buoyant equilibrium, they can not represent also the quoins and dihedral edges of a tetrahedron, held up by the strength of the crust in defiance of gravity. Perhaps it will be suggested that the crust originally had an essentially uniform composition of sima, and that sial developed from the initial quoins and dihedral edges through age-long weathering and other processes, as postulated by Lawson.[5] Such a suggestion, however, does not meet the critical objection. Any considerable distortion of the spheroidal surface to form angles or faces of a tetrahedron would produce unmistakable groups of large gravity anomalies. Although gravimetric surveys of the Earth are by no means complete, they have gone far enough for detection of tetrahedral abnormalities if they existed. The densest nets of gravity stations are in North America and Europe, on or near two of the postulated quoins. Values on the Baltic shield indicate only slight departure from balance, logically related to deglaciation. Values over the Atlantic and Pacific basins show no striking abnormalities except in strips closely related to active orogenic belts. Cumulative results of the surveys proclaim the rule of gravity (modified by the centrifugal force of rotation) in shaping the Earth.

In spite of these fundamental considerations, advocates of the tetrahedral concept present appealing arguments based on the global pattern. One of the points most emphasized, the antipodal arrangement of continents and oceans, is vulnerable on several counts. Study of a globe reveals that except for Antarctica, Australia, and southern South America, the continents are grouped within an area covering considerably less than half the surface of the sphere. The major continents, therefore, are almost inevitably antipodal to ocean. It is true that antipodal Australia falls neatly into the North Atlantic. However, Australia as a separate entity has no place in the theoretical tetrahedron. If continuous land extended and widened northward from Australia, according to theory, it would completely blanket antipodal South America. Antarctica is essentially antipodal to the Arctic Ocean; this item scores for the hypothesis. However, the Arctic Ocean truly is a puny makeshift for a tetrahedral face. The explanation that this face was invaded by three quoins and the included dihedral angles, which are 30° or 40° too far north, does not carry conviction. The tetrahedron could exist at all only by virtue of a crust that remained intact and strong. If these qualities were destroyed the figure would disappear, not persist as a distorted caricature.

Thus even the superficial arguments for a tetrahedral Earth require apologies that

[5] A. C. Lawson, *Bull. Geol. Soc. America*, Vol. 43 (1932), pp. 357–60. (Lawson's postulate had no direct relation to the tetrahedral concept.)

strain credulity. The case for the hypothesis breaks down decisively under the test of gravity values and isostasy, as explained in the foregoing paragraphs. No one relishes less than the writer this harsh verdict against a beautiful concept. However, Woolnough's complaint that geologists are neglecting the hypothesis seems to have an answer. Many of us have studied the hypothesis carefully, have found it wanting, and have regretfully placed it in the file marked "of historical interest only."

CONTINENTAL DRIFT

As Woolnough acknowledges, the tetrahedral and continental-drift concepts appear to be basically antagonistic. The former demands great strength throughout a crust which is to function as a tectonic unit; whereas large-scale differential movements such as are envisaged by proponents of the continental drift hypothesis imply a lack of fundamental strength in large segments of the outer shell. It is surprising, therefore, that a serious attempt is made to harmonize these concepts which seem mutually exclusive.

The mechanism suggested by Woolnough for moving continents thousands of miles horizontally is not outlined clearly enough for comprehension. Evidently the continental masses are considered not as essential parts of a strong crust, but as superficial plates urged along in some fashion by stresses in an underlying strong shell that cause slow migration of dihedral edges toward their rightful places in the tetrahedron. It is fair to ask why or how a change in position of a dihedral edge would involve lateral transfer of material in the crust. Moreover, if it were possible to push the continental masses into theoretical positions of dihedral edges the result would be only a false impression, since these masses rise above sea-level by virtue of their low density in relation to the sima of adjoining ocean floors. The supposed tendency toward the tetrahedral figure, if it is a reality, must be a matter of dynamics within the crust and not merely a matter of surface form.

Woolnough's concept of continental drift seems unique in its limitation of large-scale movement to the southern continents—aside from peninsular India, which has launched an aggressive assault north of the equator. Other advocates of the hypothesis are impressed with evidence purporting to establish large westward migration of North America. Woolnough discounts this evidence, acceptance of which would greatly weaken the case for the tetrahedral figure, into which North America, with its present location, is found to fit reasonably well. This necessity for compromise illustrates the unhappy quandary arising from the attempt to ride two horses that are headed in opposite directions.

Probably the writer's analysis to this point appears wholly destructive. This is not intentional, especially in view of Woolnough's frank appeal for friendly consideration of his speculations, which are offered as a possible contribution in an attack on obscure problems. Evidently he has reached two honest and firm convictions: (1) that major features of the Earth indicate an unmistakable tendency toward the tetrahedral figure; (2) that large horizontal displacements of continents have occurred, and probably are continuing. Possibly these concepts are not wholly irreconcilable if we have due regard for the element of time. Since Earth-history has been immensely long, and since our speculations may range widely in the matter of changing conditions, the writer suggests the following modification of Woolnough's combined hypothesis.

In the beginning the Earth's crust was uniformly basaltic in composition. During a long stage in its development the crust was strong enough to maintain a modified tetrahedral figure. Dihedral edges protruded to form narrow continents. Under age-long weathering, erosion, and igneous activity, the continental rocks were slowly changed to the composition of sial, as suggested by Lawson. The gradational processes constantly widened the continental areas and made them more irregular in outline. Finally a profound internal change caused weakening of the crust, until its capacity to maintain any semblance of the tetrahedral figure was lost. By this time, however, differentiation of the sialic masses was

far advanced and the continents persisted, by virtue of isostatic balance. Slow convection currents beneath the weakened crust caused large lateral displacement of some continents. These movements greatly distorted the tetrahedral pattern, but a suggestive outline remains as a relic of the earlier stage when the tetrahedral tendency functioned.

This impromptu hypothesis, like any other in a vaguely defined field, has obvious vulnerable elements. The assumed loss of strength in the crust with passage of time will be difficult to rationalize. However, the unknown terms in equations for the Earth are legion and our only hope for progress lies in multiple hypotheses. The suggestion represents the writer's best effort to meet the plea for discussion in good faith and a spirit of friendly cooperation.

REPLY TO DISCUSSION

W. G. WOOLNOUGH ("Callabonna," 8 Park Avenue, Gordon, New South Wales, Australia, May 5, 1947).—I gladly welcome Chester Longwell's fair and constructive discussion of my recent paper embodying the idea of the tetrahedroid distribution of continents and oceanic basins on the earth.

In regard to the Pacific "scar" I have clearly made too much of the traumatic injury idea. While this appeals strongly to me, it is not the only explanation of the unquestioned objective fact of the uniqueness of the Pacific Basin. In his recent presidential address to the Australasian and New Zealand Association for the Advancement of Science in Adelaide Patrick Marshall, the veteran New Zealand geologist, has stressed the antiquity of this basin and its dominating importance as a world feature, so that I find myself in very distinguished company here. From the earliest times, then, the Pacific floor appears to have been *strong* and persistent, and capable of exercising a profound influence on the rest of the surface.

In regard to my failure to consider adequately the results of geophysical research, I have not ignored this, but I believe that the concept of a relatively highly plastic earth has been unintentionally exaggerated for two reasons. Firstly, I have been led to the conclusion that we, at the present time, are living, not in a normal era, whose conditions constitute a model of phenomena which have *predominated* throughout geological history, but in the closing stages of one of the great, recurrent disatrophic eras, that of Alpine folding. During such eras plastic deformation of the earth's crust attains its maximum. Such eras are brief in duration as compared with the intervening periods of high crustal stability and presumably of high crustal strength. I am convinced that research with this idea as its basis may well mark one of the next major advances in fundamental geological appreciation. Secondly, there has been necessarily a disproportion in the *areal* distribution of intensive geophysical work referred to by Longwell. Such work has been done principally by the world's most advanced scientific nations, and therefore predominantly in western Europe, the United States, and Japan, that is, in regions where plastic deformation is strongly in evidence. Without belittling in any way the achievements of geophysics, I feel that the extrapolation of *special* results to *general* cases is as yet premature.

In regard to continental drift, I certainly do envisage direct carriage of the roots of the continents attached to progressively deeper dihedral edges, striving for ultimate symmetry of tetrahedral development. As stated, there seems reason for suspending judgment concerning the real strength of the earth until the factors there mentioned have been fully faced and thoroughly evaluated.

In the matter of continental drift, I myself am an unwilling convert to the concept. For nearly fifty years I have been profoundly convinced of the *general* accuracy of the theory of permanence of ocean basins and continental areas, and only reluctantly have been compelled by my enforced closer study of the problem of Gondwana Land, with its climatic and paleontological problems, to the realization that continental drift and continental drift

only, among the theories which have been advanced, can offer any hope of solution of the abnormalities.

The symposium, *Theory of Continental Drift*, published in 1928 by the Association, indicated that there was still a very large measure of doubt in the minds of an influential section of Northern Hemisphere geologists as to its applicability in regard to conformity between Europe and North America. I visualize, dimly it is true, that closer consideration of the tetrahedral figure may suggest certain explanations of such conformities as do exist; But I am too old to attempt this, nor will the answer be arrived at within my nearly finished lifetime; but it is a subject worthy of consideration by the coming generation of geologists, even from the negative angle.

Suggestions have been made for testing continental drift by accurate measurements of longitude. From memory, those which have been considered deal with changes between Europe and North America. If there is anything in my thesis, the results of such measurements should be entirely inconclusive. It would be interesting to know whether such comparisons have been carried out as between one of the "stable" areas and one of the three major "drifting" areas, South America, India, and Australia. Even if the drift were still at its height it is very questionable whether the crustal movements were rapid enough for detection during the infinitesimal time included within the era of measurement exact enough for the purpose. If, in addition, my contention is correct that we are living during the *closing* stages of a period of diastrophism (which I regard as synonymous with one of continental drift) failure to obtain positive results seems almost axiomatic.

I still maintain that, admittedly fragmentary and crude as is my presentation of the suggestion put forward by me, it does draw attention to a number of objective facts, not the least of which is the very close approximation to antipodal position of continents and oceans sufficiently nearly in the positions ascribed to them under the tetrahedral theory. Perfection of tetrahedral form would occur only if the sphere were homogeneous, isotropic and non-rotating, which it certainly is not, and the Pacific basin is witness of the fact. I have commented on the elongation of the supposed tetrahedron, and also on the sub-equatorial rupture of the north-south dihedral edges. The explanation of these features is unknown, but it may be remarked that the rupture is roughly symmetrically repeated in respect to the three edges.

India and South America constitute the outstanding anomalies in position. Consideration of the relations between Peninsular India and the mountain borders north and east of it constitutes one of the most striking visual suggestions of drift *toward an assigned position*. South America should be antipodal to the northern extension of the Indian Ocean, an area extending east of the axis of the Urals, now occupied by folded sediments. It is unfortunate that the extraordinary reluctance of the Russians to permit access to published geological information concerning this region militates against complete appreciation of its significance.

There are numerous other more or less clearly defined phenomena which fit into the framework of my suggestion, but which could not be referred to in a paper which had already reached excessive length; but I consider that there remain sufficient positive coincidences at least apparently fitting into its structure to outweigh its faults and omissions. I was at great pains to indicate that it was advanced only as the basis for discussion, as the result of many years of consideration of the subject, and not as a full-fledged theory. All I ask is that it be accorded fair and reasonable consideration. I hope that anything in it which is *objective* will be accepted, and that all that is inadequate will be ruthlessly eliminated and exposed to the light, so that the same errors may not be made by coming generations of geologists. I am gratified that Dr. Longwell realizes that, with all its faults, my attempt is a sincere effort to draw attention to the possibility of alternative explanations.

GEOLOGÍA DE BOLIVIA, BY F. AHLFELD[1]

VICTOR OPPENHEIM[2]
Bogota, Colombia

In his review of Ahlfeld's "Geología de Bolivia," Norman D. Newell[3] uses unaccurate statements which call for clarification and correction.

The sources of Oppenheim's Generalized Geologic Map of Bolivia, published by the Sociedad Geologica del Peru in 1944 and accompanying the memoir entitled "Mapa Geologico Generalizado de Bolivia y Memoria Explicativa"[4] are amply stated in the Introduction of the foregoing paper. Credits are given to whom ever due and references are made to a bibliography of 177 titles. The official sources and Ahlfeld's collaboration are acknowledged for western Bolivia. The greatest part of eastern Bolivia was reconnoitered by Oppenheim personally and is represented on his map as based on his own field observations and field notes made in 1942 and 1943. His personal observations and correlations account thus for more than 50 per cent of his geologic map. In no case was Ahlfeld's or any other author's manuscript perused in the preparation of the writer's map. Ahlfeld's statement to that effect is unaccurate.

While in Bolivia as consulting geologist of a major oil company the writer agreed to cooperate with the Bolivian Government in the organization of a geologic map of that country (according to documents in the writer's files). As part of the cooperation the Department of Mines received from the writer several regional geological maps covering a great part of then little known eastern Bolivia. In a letter to Oppenheim dated April 3, 1943, No. 256477, the director general of Mines and Petroleum states

> . . . You have presented to the Direccion de Minas a collection of rock samples gathered by you in your different exploration studies carried out in the Northeastern and Southeastern regions of the Republic and also a complete set of maps, geological sections and stratigraphic columns of the regions visited by you. With the present letter I have pleasure to extend to you my thanks for the contribution with which this Direccion General has been honored.

The aforementioned manuscript material was discussed and accessible to Ahlfeld, in his paper; however, he makes no mention of these sources of information, to which the writer does not object.

Although very well informed on western Bolivia, Ahlfeld, according to his own repeated statements, was not at all familiar with the sedimentary geology of the eastern part of that country. Ahlfeld's reports and bibliography deal almost exclusively with the mineralogy and geology of the Bolivian ore bodies, mainly tin and tungsten.

At the time of the writer's work in Bolivia, there were vague plans for the preparation of a geologic map of that country. No such map, however, existed and obviously could not have been shown to the writer even in a sketchy form. The writer's map became possible only after his contributions and own studies in the eastern part of Bolivia.

Newell also states that Ahlfeld sent his map to the Geological Society of America in 1943. It is interesting, that in a letter dated February 2, 1945, Ahlfeld wrote to Oppenheim, after having expressed sincere thanks for having sent him the writer's Geological Map:

> . . . I have sent a copy of my map of Bolivia to the G.S.A. [Geological Society of America] at the beginning of last year [1944]. This map together with the book "Geologia de Bolivia" will be edited

[1] Discussion received, March 7, 1947.

[2] Consulting geologist.

[3] *Bull. Amer. Assoc. Petrol. Geol.*, Vol. 30, No. 12 (December, 1946), pp. 2065–66.

[4] V. Oppenheim, "Mapa Geologico Generalizado de Bolivia y Memoria Explicativa," *Bol. Soc. Geol. Peru*, Tomo XVII (April, 1944). 22 pp.

in Buenos Aires. . . . I will be grateful if you send me the address to which I could mail you these papers.

Oppenheim left Bolivia early in 1943. A complete geological map of Bolivia was prepared by him, for his company, by the middle of 1943. A simplified form of his original map was later elaborated at the Geological Society of Peru and published in the Society's Bulletin in April of 1944. The writer does not seek any priority for his publication; he states the above facts as a matter of record.

The purpose in publishing Oppenheim's map is also stated in the Introduction of his paper (pp. 3–4)

. . . Much is left to do in order to reach a completer geological knowledge of Bolivia. This work could not be achieved by one geologist. . . . However the writer's experience has shown him that progress in geological knowledge must be based on concrete achievements, accessible to criticism for its improvement; without this condition progress would be impossible. These considerations led the writer to publish the present map, although it reflects very incomplete data . . . it remains, through more field work, to improve our knowledge . . . and finally to elaborate a new and completer map in the near future.

After many years of geological work, the writer comes to the conclusion which is not new: rocks might change, but human nature will remain unaltered.

EXCEPTIONAL OIL FIELDS IN ROCKY MOUNTAIN REGION OF UNITED STATES

CORRECTION

On page 819 of the May, 1947, *Bulletin*, Figure 17 is a map of the Oregon Basin anticline in Park (not Fremont) County, Wyoming.

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REVIEWS AND NEW PUBLICATIONS

* Subjects indicated by asterisk are in the Association library, and are available, for loan, to members and associates.

RECENT PUBLICATIONS

ARKANSAS-LOUISIANA

* "Unconformities to Play Major Role in Arkansas-North Louisiana Discoveries. Part 1, Truncation around the Monroe Uplift," by Michel T. Halbouty and George C. Hardin, Jr. *Oil Weekly*, Vol. 125, No. 5 (Houston, March 31, 1947), pp. 32-34; 4 figs.

Secondary Recovery of Petroleum in Arkansas—A Survey, by George H. Fancher, with Donald K. MacKay. 250 pp., illus.; cloth. Arkansas Oil and Gas Commission, Trimble Building, El Dorado, Arkansas. Price, $5.00.

*Secondary Recovery of Petroleum in Arkansas," by George H. Fancher and Donald K. MacKay. *Oil*, Vol. 6, No. 11 (New Orleans, Louisiana, April, 1947), pp. 19-20.

The 1945 Reference Report on Certain Oil and Gas Fields of North Louisiana, South Arkansas, Mississippi, and Alabama, Vol. II (1947). In addition to Delhi, contains West Delhi and 24 other fields; 10 stratigraphic sections; bibliography; papers by W. C. Spooner, Roy T. Hazzard, and B. W. Blanpied. Shreveport Geological Society, Box 750, Shreveport, Louisiana. Price, $10.00.

BELGIAN CONGO

*"Les Poissons fossiles du Bas-Congo et des régions voisines, premiere partie" (Fossil Fish of Lower Congo and Adjacent Regions, Part I), by E. Dartevelle and E. Casier. *Ann. Musée Congo Belge*, A, Ser. III, Tome II, Fasc. I (Tervuren, Belgium, June, 1943). 199 pp., 16 pls., 60 figs., circa. 10.75×14.75 inches. Pages not bound, folio. Printed by Van Campenhout, 22 Rue des Paroissiens, Brussels.

BRAZIL

*"Bibliografia e Índice da Geologia do Brasil, 1941–1942" (Bibliography and Index of the Geology of Brazil, 1941–1942), by Dolores Iglesias and Maria de Lourdes Meneghezzi. *Brasil Div. Geol. Min. Bol. 117* (Rio de Janeiro, 1944). 35 pp. In Portuguese.

CALIFORNIA

"Geology of Reef Ridge, Coalinga District, California," by Ralph Stewart. *U. S. Geol. Survey Prof. Paper 205-C*, 1946 (1947), pp. 81-115; Pls. 9-17, Figs. 10-13. For sale by Superintendent of Documents, Government Printing Office, Washington 25, D. C. Price, $0.75.

*"Schist Surface of the Western Los Angeles Basin," by J. Lloyd White. *California Oil Fields*, Vol. 32, No. 1 (California Div. of Oil and Gas, San Francisco, January-June, 1946), pp. 3-11; subsurface map; 2 tables.

*"Consolidated Index of Publications of the Division of Mines and Predecessor State Mining Bureau, 1880-1943, Inclusive," *Californa Div. Mines Bull. 131* (Ferry Building, San Francisco, September, 1945; published in 1947). 872 pp. Price, $8.75.

*"Geologic Section from the Sierra Nevada to Death Valley, California," by Richard H. Hopper. *Bull. Geol. Soc. America*, Vol. 58, No. 5 (New York, May, 1947), pp. 393–432; 6 pls., 3 figs.

CARIBBEAN BASIN

*"Problems of Earth Deformation Illustrated by the Caribbean Sea Basin," by Walter H. Bucher. *Trans. New York Acad. Sci.*, Ser. II, Vol. 9, No. 3 (New York, January, 1947), pp. 98–116; 1 fig.

CHINA

*"Silurian Stratigraphy of the Malung and Kutsing Districts, Eastern Yunnan," by Y. C. Sun and H. C. Wang. *Bull. Geol. Soc. China*, Vol. 26, Nos. 1–4 (Nanking, December, 1946), pp. 83–99; 2 figs.

*"Report on Geological Investigation of Some Oil Fields in Sinkiang," by T. K. Huang, C. C. Young, Y. C. Cheng, T. C. Chow, M. N. Bien, and W. P. Weng. *Mem. Geol. Survey China*, Ser. A, No. 21 (Nanking, February, 1947). 188 pp., 14 pls.

*"Bibliography of Chinese Geology," by T. C. Tseng. *Geol. Survey China* (Nanking, December, 1946). 114 pp. Bibliography of geology and allied sciences of Tibet and regions west of Chinshachiang.

COLOMBIA

"Seismic and Tectonic Map of Colombia," by J. E. Ramirez and L. Forero Duran. *Boletin Gráfico*, No. 7 (1947). Published by the Banco de la Republica, Bogotá, Colombia.

Bulletin of the Colombian Petroleum Institute, Vol. 1, No. 1 (Bogotá, Colombia, February, 1947). 64 pp., illus. A new Colombian publication for "a better knowledge of the oil industry." Office of publication, Calle 13, No. 8–23, Bogotá. Subscription price, Col. $8.00 per year.

EUROPE

*"Three Stages in the Evolution of Alpine Geology: De Saussure-Studer-Heim," by Emmanuel de Margerie. *Quar. Jour. Geol. Soc. London*, Vol. 102, Pt. 3, No. 407 (London, December, 1946), pp. xcvii-cxiv; bibliography.

*"Oesterreichs ölproduzierende und ölhöffige Gebiete" (Prospective and Oil-Producing Regions in Austria), by Rudolf Grill. *Bohrtechniker-Zeitung*, No. 1 (Erdöl-Dienst, Wien 72, Postfach 87, Austria, January, 1947), pp. 3–6. In German.

*"Resultats des recherches geologiques du pétrole aux environs de Czerchawa et de Sprynia" (Results of Geological Exploration for Petroleum in the Vicinity of Czerchawa and Sprynia (Poland)), by H. Teisseyre. *Rocznik Polskiego Towarzystwa Geologicznego*, Vol. 15 (Geological Society of Poland, 6 St. Anna Street, Krakow, Poland, 1939), pp. 35–41; 2 pls. In French (also in Polish, pp. 28–35).

GENERAL

*"The Electric Pilot in Permeability Surveys," by L. B. Swan. *Oil Weekly*, Vol. 125, No. 1 (Houston, March 3, 1947), pp. 42–46, 10 figs.

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*"Importance of Clay Studies in Water Flood Operations," by Richard V. Hughes. *Producers Monthly*, Vol. 11, No. 4 (Bradford, Pennsylvania, February, 1947), pp. 13–16.

*"Deep-Well Camera," by O. E. Barstow and C. M. Bryant. *Oil and Gas Jour.*, Vol. 45, No. 45 (Tulsa, Oklahoma, March 15, 1947), pp. 74–75, 92–93; 3 figs.

**Ibid.*, *Oil Weekly*, Vol. 125, No. 10 (Houston, May 5, 1947), pp. 33–39; 12 figs.

*"An Evaluation of Present-Day Geophysical Exploration for Oil. Part 1," by Sylvain J. Pirson. *Oil Weekly*, Vol. 125, No. 2 (Houston, March 10, 1947), pp. 45–53; 2 figs., 3 tables.

"Fossil Vertebrates from Western North America and Mexico," by E. L. Furlong, Lore Rose David, E. Raymond Hall, Robert E. Wallace, and Hildegarde Howard.

Carnegie Inst. Washington Pub. 551 (Washington, D. C., 1946). Contributions to paleontology series. 195 pp., 31 pls., 33 text figs. 6.875×10 inches. 8 articles issued between 1943 and 1946. Price: paper cover, $2.50; cloth, $3.00.

*"Paleontologist or Geologist," by J. Brookes Knight. *Bull. Geol. Soc. America.* Vol. 58, No. 4 (New York, April, 1947), pp. 281–86.

*"Functions of Vertebrate Paleontology in the Earth Sciences," by Edwin H. Colbert. *Ibid.*, pp. 287–92.

*"Preliminary Maps of the Oil and Gas Investigations Series." *U. S. Geol. Survey* (March 15, 1947). Brief descriptions of 69 preliminary maps, 28 preliminary charts, and 17 miscellaneous maps and reprints relating to the general oil and gas program of the Geological Survey. Obtainable on request from Director, Geological Survey, Washnigton 25, D. C.

**Early Geophysical Papers*, by many authors. 848 pp., illus. 52 papers by men outstanding in the development of geophysical exploration methods. Society of Exploration Geophysicists, Box 1614, Tulsa 1, Oklahoma. Price, $6.00.

"Oil-Bearing Basins, Their Facies and Conditions of Accumulation of Source Material for the Formation of Oil," by B. V. Weber. *Comptes Rendus (Doklady) Acad. Sci. URSS*, Vol. 53 (Moscow, 1946), p. 447. In English.

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PUBLICITY FOR GEOLOGY AND GEOLOGISTS

After Julius Caesar refused the crown three times and fell down in the market-place and foamed at the mouth and was speechless—he was an epileptic—two of his future assassins dialogued as follows (Julius Caesar, Act 1, ii,).

Cassius: Did Cicero say anything?
Casca: Ay, he spoke Greek.
Cassius: To what effect?
Casca: Nay, an I tell you that, I'll ne'er look you i' the face again: but those that understood him smiled at one another and shook their heads; but for mine own part, it was Greek to me.

It is generally agreed that geologists as a group—and most other scientists—should use less "Greek" in their relations with the layman, especially the influential layman, and should publicize widely their worth, accomplishments, and needs. Attention is directed, therefore, to the wide-spread and favorable publicity recently given two long-time members of the Association who were petroleum geologists and are now high executives in industry.

The cover of the March 24 number of *Time* features a picture of Eugene Holman, president of the Standard Oil Company (N. J.), over the statement "Eugene Holman, International Oilman," and the cover of the April 5 issue of *Business Week* shows a picture of Fred A. Davies, vice-president of the Arabian American Oil Company, over the statement "Fred A. Davies, the oil he found in Saudi Arabia bulks large in the world petroleum pattern." These featured articles outline the histories of these men, the part that geologists play in the petroleum industry, and petroleum developments in the Middle East and elsewhere.

Geology, and especially petroleum geology, is continuously assuming a maturer stature in world affairs, and, as is well known in the petroleum industry, geologists are moving rapidly into policy-making positions. It seems highly desirable, therefore, that members of the Association increase their efforts to assist their committee on applications of geology, K. K. Landes, chairman, in informing the public on all phases of geology and especially on the natural occurrence of oil and gas underground, the methods of searching for these substances, and the methods of exploiting them.

Geology is now lusty and all geologists should heed the dictum of president Isaiah Bowman of The Johns Hopkins University that relaxation and complacency in this divided world are evils as great as atom bombs.

C. E. DOBBIN

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MEMORIAL

JOSEPH ARTHUR GOODSON

(1910–1946)

When, in the early morning hours of December 7, 1946, radio stations announced the name of Joseph A. Goodson of Clay City, Illinois, as one of the first identified victims of the Winecoff Hotel fire at Atlanta, Georgia, geologists and others of the oil fraternity throughout the Illinois basin area were saddened and stunned. Then fearful apprehension spread in the Olney area where it was known that Mrs. Goodson and their two small children were with Joe en route to Florida. Within a few hours, the frightful apprehension changed to a sad reality. Later examination of their burned-out rooms revealed the family had withstood the flames to the last moment when there had to be a choice between certain cremation and the chance of jumping into a fireman's net. They chose the chance to live; but there was no net to break their fall.

The four bodies were taken to the home of Joe's mother, Mrs. G. Frank Vaughan, at Lexington, Kentucky, and were laid to rest by the side of his father in the Lexington Cemetery. Former classmates and fraternity brothers from the University of Kentucky were pallbearers.

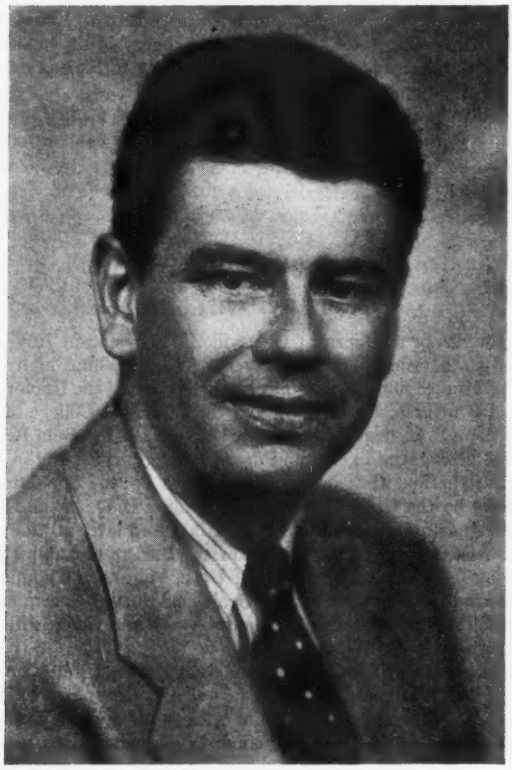
Joseph Arthur Goodson was born, November 26, 1910, in Dixon, Kentucky, the son of Dr. Joseph Arthur Goodson and Lalla Rookh Rasco Goodson. When the son was one year old, Dr. Goodson was appointed superintendent of the Eastern State Hospital at Lexington, thus causing the family to move to Lexington. Joe attended public grade schools in Lexington and, after the untimely death of his father, he was sent to preparatory school at the Kentucky Military Institute, Lyndon, Kentucky. During his senior year at the Military Institute, he was made Cadet Major, the highest rank that could be attained by a member of the Cadet Corps. In all probability, his training at this school helped develop his heritage of fine qualities which so definitely marked him as a courteous gentleman throughout the remainder of his life.

After graduation from the Kentucky Military Institute, he entered the University of Kentucky where he received his A.B. degree in geology in 1935. At the University, he was a member of Keys, a geological honorary fraternity, and of the Kappa Alpha fraternity of which he was president for one year. During his senior year, he worked part time as a student instructor in geology.

In January, 1936, he went to work for the Gulf Refining Company in Michigan, starting to learn the various activities of a large producing oil company. During his first summer in Michigan, he suffered the first of a series of serious accidents which followed him to the fateful end at Atlanta. While working on a pumping well, his foot was crushed by the machinery. This accident resulted in his confinement in a hospital for many long months. Upon recovery, he returned to the Gulf organization and worked as a geological scout until January, 1941. His next broadening experience was obtained by one year's work with the Halliburton Oil Well Cementing Company in the Michigan fields. In January, 1942, he was employed as geologist by The Pure Oil Company and was stationed at Clay City, Illinois, where he was still working at the time of his death.

In August, 1941, Joe was married to Gladys Grace Carlson, the daughter of Mr. and Mrs. Edward A. Carlson of Grand Rapids, Michigan. Mrs. Goodson was born in Chadron, Nebraska, June 25, 1917, and was graduated from South High School in Grand Rapids, Michigan, in June, 1935. After special training at the Lucid Secretarial School, she was

employed by the American Production Company where she did some special work with Max W. Ball while he was writing his book, *This Fascinating Oil Business*. Her familiarity with the oil industry, together with her charming and lovable personal characteristics, fitted Gladys for the ideal companion of an exploitation geologist. To further expand the beauty of this companionship, a son, Joseph Arthur III, was born, September 24, 1942,



JOSEPH ARTHUR GOODSON

and a daughter, Barbara Beck, March 4, 1945. The children reflected the congenial characteristics of the parents and a visit in the Goodson home caused friends to observe the near approach to the ideal in American family life.

Joe Goodson was a competent, reliable geologist who never left a job or a problem until it was completed. His familiarity with drilling, cementing, and production operations drew the respect of all departments within his company. His pleasing personal characteristics, his willingness to help on any job, and his congenial participation in all activities of his community, endeared him to all with whom he came in contact. He became a member of the A.A.P.G. in 1944.

On October 1, 1945, Joe suffered an automobile accident from which there seemed little chance for his recovery, yet his determination to live and the skill of his doctors enabled him to leave the hospital after nearly three months of trying confinement. After a few weeks at home and six weeks of sunshine in Florida, he was back at his desk, working the hours permitted by his doctors. In October, 1946, just when he was expecting a full release from his doctors, he was stricken with pneumonia which made it necessary for him to return to the hospital for another four weeks. When he had regained enough strength, his doctors and employers recommended his return to Florida for another long period of rest. With new hopes for the complete recovery of his health and with great plans for a happy future, he and his family were en route to Florida on the fateful night they were caught in the hotel fire at Atlanta.

Why fate should close the lives of this lovable young family just when they had begun to bloom into usefulness, is a question that appears to have no earthly explanation.

DARSIE A. GREEN

Olney, Illinois
March 19, 1947

CHARLES DWIGHT AVERY

(1877–1947)

Charles Dwight Avery was born at Galesville, Wisconsin, on July 29, 1877, the son of Henry N. and Catherine S. (Fowler) Avery. After finishing high school he moved with his parents to Minneapolis, Minnesota, where he entered the University of Minnesota and received an A.B. degree. He then entered the Michigan College of Mines where he was graduated with an E.M. degree in 1903. He belonged to the Beta Beta Phi fraternity. From 1903 to 1908 he engaged in coal and metal mining, principally in Utah, and superintended some construction work in Oregon. In 1908 he was appointed a mineral and Carey Act Inspector by the United States General Land Office of the Department of the Interior, with headquarters at Salt Lake City, Utah, and later at Cheyenne, Wyoming. He remained with the General Land Office, now the Bureau of Land Management, from 1908 to 1920, doing field work in the states of Utah, Montana, Wyoming, and Colorado. In 1920 he transferred to the United States Geological Survey as a mining engineer, and later was appointed a senior geologist, remaining with the Geological Survey until his death.

Mr. Avery was a member of the American Association of Petroleum Geologists, the American Society of Civil Engineers of which he was president of the District of Columbia Section in 1927 and 1928, and the Geological Society of Washington. He was a Mason and a member of the Scottish Rite, Cheyenne, Wyoming, and Korein Temple Shrine, Rawlins, Wyoming. On December 6, 1917, he was married to Myra K. Graham, at Storm Lake, Iowa. He is survived by his widow and a daughter, Mrs. Nancy Kuhl of California, Pennsylvania.

While with the General Land Office, Mr. Avery examined and reported on Carey Act Irrigation Projects as to the adequacy of the water supply, the facilities for getting water on the land and the estimated cost. He also reported on the feasibility of proposed projects from an engineering and financial viewpoint.

Mr. Avery's transfer from the General Land Office to the United States Geological Survey in February, 1920, antedated by about two weeks the approval by President Wilson of the general leasing law for non-metalliferous minerals in Federal lands. To the adoption of sound policies and expeditious procedures in the administration, particularly of the oil and gas provisions of this important legislation, the remaining 27 years of his public service were devoted. His personal knowledge of men and conditions throughout

the states west of the 100th Meridian was an invaluable asset to the Geological Survey in the discharge of its responsibilities under the mineral leasing law, and a never failing source of aid and inspiration to his associates. The simple record of basic determinations made and reported to administrative agencies, in these 27 years, on the structural situation and relation to other holdings of the same applicant, of the lands described in more than 57,000 applications for oil- and gas-prospecting permits on public lands and more than 35,000 applications for oil and gas leases on such lands, together with determination of the *bona fide* potential value for oil and gas of more than 34,500 land parcels affected by conflicting applications for homestead and mineral-prospecting rights, respectively, all accomplished with less than 100 appeals from his findings in the entire period, is in itelf an eloquent tribute both to his judgment and to his capacity for constructive work contributing to the highly successful venture of his Government into the field of oil and gas leasing. It is only a part, however, of his contribution, which also included most of the spade work involved in defining the "known geologic structure" of producing oil and gas fields containing Federal lands, as an administrative basis for distinguishing between land parcels to be leased for oil and gas by competitive bidding and others that might be leased to the first applicant therefor. The record of 250 outstanding definitions of such structure on January 31, 1947, aggregating more than 4,326,000 acres in 9 public-land states, is mostly of his making, and constitutes a lasting monument to the utility of his unpublicized but invaluable public service.

In the field of conservation he was an ardent advocate, from its inception, of the policy of unit operation for oil and gas fields containing Government lands.

He participated actively in the conferences and discussions leading to the amendment of the oil and gas provisions of the Federal leasing law in 1930, 1931, and 1935, to authorize and encourage unit or cooperative development of such fields or pools, and his only literary contribution in the period of his Survey employ, aside from the thousands to his credit in the files of the Interior Department and its agencies, was as senior author of a paper on this subject, presented at the Dallas meeting of the American Association of Petroleum Geologists, March 23, 1934, and published in Vol. 18, No. 11, of its *Bulletin*, November, 1934.

BENJAMIN E. JONES

Washington, D. C.
April 3, 1947

CARL WESLEY HUBMAN

(1905–1947)

Carl Hubman died on February 15, 1947, when a DC-4 Avianca airliner crashed into the almost vertical face of El Tablazo, a mountain about 30 miles northwest of Bogota, Colombia. He is survived by his parents, Mr. and Mrs. Charles Hubman of Boulder, Colorado, and by his brother, Ralph G. Hubman of Mt. Pleasant, Michigan.

Carl was born on February 7, 1905, in Boulder, Colorado, where he grew up and attended public schools. In high school he was class president in both sophomore and junior years and he graduated as class valedictorian. He entered the University of Colorado on a scholarship granted by the University in recognition of his high school record. He majored in geology and graduated in 1927, receiving an A.B. degree *cum laude*. During his undergraduate days he was elected a member of Arch, an honorary sophomore fraternity at the University of Colorado. At graduation he received the first D. W. Brunton Award for meritorious work in geology. During his university years he did geological field work during several summer vacations for the Midwest Refining Company in New Mexico, Utah, and Arizona.

After graduation he entered the graduate school at the University of Colorado, having been granted a research fellowship in the department of geology, but in February, 1928, he left to accept employment with the Lago Petroleum Corporation at Maracaibo, Venezuela. Upon completion of his eighteen months contract with the Lago Petroleum Corporation he returned to the United States and worked for a short time with the

CARL WESLEY HUBMAN

Louisiana Oil Refining Company. In September, 1930, he joined the geological staff of The Texas Company in the West Texas-New Mexico division. In 1933 he was sent to the Argentine on the staff of Ultramar SAPA, this being a Texas Company joint-interest affiliate. There he did outstanding work in Salta and Neuquen. In January, 1937, he was transferred to the Colombian Petroleum Company, jointly owned by Texas and Socony, and took a leading part in mapping the Barco Concession. In 1938 he became chief geologist of that company and continued in that capacity until mid-1943 when he took military leave of absence and enlisted in the Army of the United States. He was assigned to the 1876th Engineering Aviation Battalion, Headquarters Company. He

trained at March Field and Geiger Field and served with the aforementioned battalion in India, Burma, and China. He was honorably discharged in October, 1945. It was rather characteristic of Carl that he enlisted as a buck private at the age of 38 and saw the war through the hard way. He never asked favors.

In January, 1946, Carl rejoined The Texas Company and spent almost a year in subsurface work at Corpus Christi, Texas. In December, 1946, he was transferred to Bogota, Colombia, as assistant manager in charge of operations for the Texas Petroleum Company, Colombian division. He was working in that capacity at the time of his tragic death.

Carl was a member of Phi Beta Kappa, Sigma Xi, Sigma Nu fraternity, the American Association of Petroleum Geologists, and was a Fellow of the American Geographical Society. He was co-author of a paper entitled "Geology of the Barco Concession," published in the *Bulletin* of the Geological Society of America in October, 1944.

The foregoing outlines a career all too short. Those who worked with him in the field or the office knew him as a man of outstanding ability who should have a bright future. He was that rare combination, a really first-class field geologist who was also a good office man. He could turn out a clear, concise, and well organized report, train a group of young geologists just out of school to do effective work in the jungle, and manage a geological department so it ran smoothly. He had the instincts of a research man but he kept his feet on the ground and never lost sight of his objective. He had plenty of imagination but it was coupled with a keen critical faculty and any hypothesis, his own or that of others, had to stand up to rigid investigation.

Carl had a gay and lovable personality that made him a host of friends wherever he went. He was a hard worker but no solemn grind, and he knew how to relax and play when the time came. In the city he was a man of the world, neat, businesslike, friendly but somewhat reticent, and at home in any company. In the office he never forgot that he had been a field man and that the office was there to serve the field. In the woods he was a pathfinder and a pioneer like only a few. "Hub" ranged the earth and there are those to mourn him who knew him from Patagonia to Colombia and from the Rocky Mountains to Kunming. Among his associates of the deep bush his loss leaves a gap which will never be filled.

FRANK B. NOTESTEIN

Bogotá, Colombia
April 7, 1947

JOSEPH MEADOWS DAWSON

(1895–1946)

Joseph Meadows Dawson was born in northern Louisiana on September 10, 1895, and later moved to San Benito, Texas, where he was reared. He died in San Antonio, Texas, on August 9, 1946, as a result of a heart attack.

Joe entered the University of Texas in the fall of 1915, but his education was interrupted by World War I, when he entered the first Officers Training Camp at Leon Springs in 1917. He was transferred to the Air Corps after graduation. During the war Joe held the rank of Captain and was instructor at the Memphis Flying Field. When the war closed, he was commandant of the Orlando, Florida, Field.

After the war, Joe returned to the University of Texas and majored in geology. He received his degree there in 1921. Joe's college fraternity was Theta Xi. He was also a member of Sigma Gamma Epsilon, honorary geological fraternity, and he was vice-president of the University of Texas' Chapter of S.G.E. during the year 1920–1921.

In the fall of that year he went to work for the Gulf Production Company doing surface work along the fault line in Texas. In 1923 and 1924 he worked for the Venezuelan Gulf Company in the Maracaibo Basin. He then returned to San Antonio, Texas, with the Gulf Company, where he did surface and subsurface geological work. Joe was one of the first

JOSEPH MEADOWS DAWSON

geologists in Southwest Texas to recognize the possibilities of the Salt Flat area. He got his company into this field early.

In June, 1932, Joe was made zone agent for the Gulf Company at San Antonio, which position he held until his resignation in June, 1939. He then moved to Jackson, Mississippi, where he had charge of geological work for Wheelock & Collins, W. L. Pickens, and H. J. Porter. In 1941 he moved to Evansville, Indiana, for these operators, and found some small

production in eastern Indiana for them. In 1942 he went with H. L. Hunt in charge of extensive work in Illinois and Michigan. He was assisted in his geology by Grady M. Kirby.

In 1944 Joe returned to Jackson, Mississippi, where he did consulting work, and was instrumental in getting several wells drilled. His technical work was always of the highest quality.

Joe is survived by his wife, Virginia Dawson, and their two children, Joseph M., Jr., and Dorothy, of San Antonio, Texas; three sisters, Mrs. L. W. Anderson, Norman, Oklahoma; Mrs. Nina Orr, Shreveport, Louisiana; Miss Erle Dawson, San Antonio, Texas; and six brothers, Dr. DeWitt Dawson, San Benito, Texas; Raleigh Dawson, Washington, D. C.; W. Y. Dawson, Jr., Rio de Janeiro, Brazil; E. W. Dawson, Corpus Christi Texas; W. S. Dawson, Rodeo, California; and H. M. Dawson, San Antonio, Texas.

There are probably few members of the A.A.P.G. who have had more friends than Joe. His mind was keen and active, and he took a great interest in geological problems in those areas in which he worked, especially Southwest Texas. He was an enthusiastic member of the A.A.P.G., serving on many committees, and was always ready to help younger geologists to get started in the profession. He served as president of the South Texas Section of the A.A.P.G. in 1935, and had previously served as vice-president and secretary-treasurer of the same organization. He was a member of the San Antonio Petroleum Club and its vice-president in 1937.

Joe's hobbies in life were hunting, fishing, and raising bird dogs, and he was widely known throughout the Southwest as a crack shot. He was a colorful and lovable character. We mourn the loss of a fine geologist, a great sportsman, and a true friend.

DILWORTH S. HAGER

Dallas, Texas
May 12, 1947

BULLETIN OF THE AMERICAN ASSOCIATION OF PETROLEUM GEOLOGISTS
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AT HOME AND ABROAD

CURRENT NEWS AND PERSONAL ITEMS OF THE PROFESSION

A. N. MURRAY, professor of geology at the University of Tulsa, gave a lecture on "The General Geology of the Uinta Basin" before the Shawnee Geological Society, March 13, at the Aldridge Hotel, Shawnee, Oklahoma.

NIELS C. GEORGESEN has resigned as district geologist for the Tide Water Associated Oil Company to enter the independent consulting field. He will make headquarters at 504 Hulman Building, Evansville, Indiana.

JOSEPH S. IRWIN, consulting geologist, Calgary, Alberta, is president of the Association of Professional Engineers of Alberta.

A Yankqui in Patagonia, "A Bit of Autobiography," by BAILEY WILLIS, emeritus professor of geology of Stanford University, California, has been published by the Stanford University press ($3.00).

The 18th Session of the International Geological Congress will be held in London, England, from August 25 to September 1, 1948. Headquarters will be in the building of the Geological Survey and Museum, Exhibition Road, South Kensington, London, S.W. 7; all communications should be sent to this address, attention of the General Secretaries, 18th Session International Geological Congress. Numerous guided excursions in England, Wales, Scotland, and Ireland will take place both before and after the Congress. President C. E. DOBBIN has appointed J. HARLAN JOHNSON, of the Colorado School of Mines, Golden, and A. RODGER DENISON, of the Amerada Petroleum Corporation, Tulsa, as A.A.P.G. delegates.

ROBERT W. BLAIR has resigned from the U. S. Geological Survey and has accepted a position as geologist in the Denver, Colorado, office of the Continental Oil Company.

H. C. VANDERPOOL has resigned from the Seaboard Oil Company in order to accept appointment as chief geologist with the Texas and Pacific Coal and Oil Company, Fort Worth, Texas.

WALTER K. LINK has resigned as exploration manager of the Tropical Oil Company, Bogota, Colombia, and as exploration coordinator of the International Petroleum Company in Colombia, Ecuador, and Peru. In his new position he is chief geologist of the Standard Oil Company (New Jersey), 30 Rockefeller Plaza, New York.

GEORGE GAENSELEN, geologist with the Standard Oil Company of Egypt, has returned to Cairo after a recent "stateside" vacation.

GARTH W. CAYLOR has resigned his position as geologist with the Shell Oil Company, Inc., Tulsa, Oklahoma, to enter practice as an independent consulting geologist. His office address is Room 206, Chestnut-Smith Building, Tulsa, Oklahoma.

JAMES D. WEIR, University of Saskatchewan, has been appointed chief geologist for the California Oil Company, Ltd. He is a past-president of the Alberta Society of Petroleum Geologists.

BOB HANCOCK, geologist with the Magnolia Petroleum Company for a number of

years, has resigned to enter practice as an independent consultant. His office is at 818 Braniff Building, Oklahoma City, Oklahoma.

LOUIS H. LUKERT, geologist with The Texas Company, Tulsa, spoke before the Tulsa Geological Society on the evening of April 7. His subject: "Lower Permian and Pennsylvanian Subsurface Correlations in North-Central Oklahoma."

LOUIS H. DESJARDINS, Creole Petroleum Corporation, Caracas, Venezuela, has been on a recent vacation in the United States.

E. G. DAHLGREN, assistant secretary, Interstate Oil Compact Commission, Oklahoma City, Oklahoma, presented a paper, "Underground Natural Gas Storage," before the American Gas Association meeting in Chicago, Illinois, on May 1.

A regional meeting of the Society of Exploration Geophysicists was held in Tulsa, Oklahoma, May 22, under the auspices of the newly organized Geophysical Society of Tulsa. Other regional meetings were held in Houston, Texas, and Pittsburgh, Pennsylvania.

NORMAN D. NEWELL, professor of geology at Columbia University, New York, is heading a summer geological expedition into an unexplored region on the high eastern slopes of the Peruvian Andes. Geologists from Columbia University, the American Museum of Natural History, and the Instituto Geologico de Peru will participate.

JAMES GILLULY, University of California at Los Angeles, has been elected to the National Academy of Sciences.

Two hundred and twenty-four geologists participated in a 3-day field conference in the western part of the Ouachita Mountains conducted by the Tulsa Geological Society, May 8–10. Under the leadership of T. A. HENDRICKS, U. S. Geological Survey, key exposures were visited throughout the area covered by new *U. S. Geological Survey Preliminary Map 66*, Oil and Gas Investigations Series (May, 1947). HUGH D. MISER, to whom the Guide Book is dedicated, led the trip into the Potato Hills.

ROBERT B. CAMPBELL, of Gulf Hammock, Florida, addressed the Florida Educational Association, April 18, at its annual meeting in Tampa on the subject, "Earth Sciences in the Public School Curriculum." Campbell has been busy addressing various business men's clubs in the Miami area on "Petroleum Exploration in Florida."

The Rocky Mountain Association of Geologists, Denver, Colorado, held a field trip, June 16–19, in the general region of Golden, Leadville, Glenwood Springs, and Rifle. Trip leaders were VANDERWILT, KOSCHMANN, TWETO, VAN TUYL, JOHNSON, SHAW, and LAVINGTON.

HENRY SCHWEER, consultant of Wichita Falls, Texas, spent several months since January 1 in Central America, engaged in surface work.

PERCY W. DONOVAN resigned as vice-president and manager of the contract drilling division of E. J. Longyear Company, Minneapolis, Minnesota, June 6, after 42 years of active service.

J. A. ALLAN, professor of geology at the University of Alberta, Edmonton, is head of the department of geology at that institution. An error was made in crediting P. S. WARREN, his colleague, as head of the department, in the authorship of the geological note by DECKER, WARREN, and STELCK, "Ordovician and Silurian Rocks in Yukon Territory, Northwestern Canada," on page 149 of the January *Bulletin*.

The Pacific Section (Los Angeles, California) annual spring picnic was held at the Standard Oil Company picnic grounds in Pico Canyon, May 23–24. HAROLD E. RADER was in charge of arrangements.

At the Pacific Section luncheon meeting, Clark Hotel, Los Angeles, June 5, F. A. HUFF, of the Southern Counties Gas Company, spoke on "Texas Gas for California."

The Geological Forum of the Pacific Section of the Association holds frequent meetings, attended by 100–150 geologists.

The annual lectures in petroleum geology at the University of Michigan were given on May 1 and 2 by IRA H. CRAM, of the Pure Oil Company, and past-president of the A.A.P.G.

Recent additions to the staff of Geophoto Services in Denver are BERNARD M. BENCH, formerly consulting geologist, ROBERT B. MCCULLOCH, formerly with the Stanolind Oil and Gas Company at Craig, Colorado, and C. MAYNARD BOOS, formerly Rocky Mountain division geologist for the Barnsdall Oil Company.

LAURENCE BRUNDALL, vice-president of Geophoto Services, Denver, presented a paper on photogeology at a joint meeting of the Southwestern Division of the A.A.A.S. and the Colorado-Wyoming Academy of Science which was held May 1–3 at Colorado Springs, Colorado.

New officers of the East Texas Geological Society, Tyler, Texas, for the year 1947–1948 are: president, T. H. SHELBY, JR., Humble Oil and Refining Company; vice-president, L. F. LEES, Phillips Petroleum Company; secretary-treasurer, WALTER E. LONG, Magnolia Petroleum Company.

The Rift Club of Southern California, under the presidency of EDWIN VAN AMRINGE, assistant professor of geology at Pasadena Junior College, held its final field excursion for the year on April 18 to 20. D. FOSTER HEWITT, staff geologist of the United States Geological Survey, led the caravan of 22 cars on a study of the complex overthrusting in the Ivanpah Quadrangle, eastern San Bernardino County. For the coming year JOHN C. HAZZARD, of the Union Oil Company of California, was elected president, and KENNETH B. GARNER, of San Bernardino, secretary-treasurer.

After 9 years with the Schlumberger Oil Well Surveying Corporation in the Gulf Coast region and Oklahoma as chief engineer and district manager, RICHARD D. BUCK resigned, May 1, to open a consulting office. He may be addressed at 1704 North Market, Shawnee, Oklahoma.

JOHN R. BALL, professor emeritus of geology at Northwestern University, Evanston, Illinois, is teaching geology, mineralogy, and paleontology at the University of Kansas City, Kansas City, Missouri.

ROBERT L. BATES, for the past 6½ years petroleum geologist with the New Mexico Bureau of Mines and Mineral Resources, Socorro, has resigned, effective August 1. He will become assistant professor in charge of the department of geology at the Newark Colleges of Rutgers University, Newark, New Jersey.

HARRY G. HADLER, geologist with the Stanolind Oil and Gas Company, talked on "South and West Moore Oil Fields" before the Shawnee Geological Society, April 25. New officers were elected: president, HENRY ANDREW CAMPO, Atlantic Refining Company, Shawnee; vice-president, FRED J. SMITH, Sinclair Prairie Oil Company, Seminole;

secretary-treasurer (re-elected), MARCELLE MOUSLEY, Atlantic Refining Company, Shawnee, Oklahoma.

BETTY KELLETT NADEAU has been appointed a research associate with the title of lecturer in geology in the geology department of Washington University, St. Louis, Missouri.

C. E. DOBBIN, of the United States Geological Survey, Denver, Colorado, and C. J. HARES, of the Ohio Oil Company, Boulder, Colorado, represented the Association at the Mountain-Plains Regional Conference of the United Nations Educational, Scientific and Cultural Organization in Denver, May 15, 16, 17. President Dobbin addressed a division of the conference on "Petroleum in World Affairs."

At its annual business meeting on May 16, 1947, the Pittsburgh Geological Society elected the following officers: president, SHAILER S. PHILBRICK, United States Engineers; vice-president, JOHN T. GALEY, independent oil and gas operator; secretary, DAVID K. KIRK, Gulf Research and Development Company; treasurer, CHARLES H. FELDMILLER, Equitable Gas Company. The final meeting consisted of a full-day symposium on the Trenton and sub-Trenton rocks of the Appalachian basin. More than 200 geologists, representing 13 states, attended this meeting to hear 10 speakers present their papers. This symposium was intended to arouse further interest in the deeper rocks of the Appalachian basin as possible sources of new oil and gas reserves.

RUSSELL V. JOHNSON, consulting geologist formerly of Oak Harbor, Washington, has opened an office at 600 Mercantile Building, Denver, Colorado.

LEWIS H. BOYD has resigned from the Brown Geophysical Company to accept a position as director of the gravity-meter and instrument rentals division of the Western Geophysical Company, Tulsa, Oklahoma.

C. L. SEVERY has resigned from the U. S. Bureau of Mines in order to engage in consulting geological work in oil and gas. His address: 1770 Guinda Street, Palo Alto, California.

G. W. GULMON and N. W. JOHNS, after 8 years of employment by the California Company in foreign and domestic geological and geophysical work, have resigned to form the consulting firm of Gulmon and Johns in Natchez, Mississippi.

PAUL B. FAHLE is in charge of the Shreveport, Louisiana, district office of the Plymouth Oil Company.

J. A. MULL has left the Superior Oil Company to organize Central Exploration Company, Inc., 306 Kerr-McGee Building, Oklahoma City. The firm engages in geological and seismograph exploration.

ALVA C. ELLISOR has retired from the Humble Oil and Refining Company and may be addressed at 1718 Avenue N, Galveston, Texas.

LAURENCE BRUNDALL, vice-president of Geophoto Services, Denver, Colorado, addressed a joint meeting of the Appalachian Geological Society and the Engineers' Society of Western Pennsylvania held in Marietta, Ohio, May 23. His paper was on photogeological evaluation.

HALL TAYLOR is making a stratigraphic study of Ethiopia for the Sinclair Petroleum Company. He flew to Italy early in June to examine Italian collections, and has now gone

to Ethiopia for work on the ground. He plans to resume his teaching duties at Columbia University, New York City, about December 1.

H. W. THOMS, geologist with Creole Petroleum Corporation, Caracas, Venezuela, is spending July and part of August on vacation in the states, where he may be reached in care of L. Banes, 224 Pacific Street, Bakersfield, California.

New officers of the Tulsa Geological Society, elected May 23, are as follows: president, CHARLES G. CARLSON, consulting geologist; first vice-president, JERRY E. UPP, Amerada Petroleum Corporation; second vice-president, L. E. FITTS, JR., Sinclair Prairie Oil Company; secretary-treasurer, V. L. FROST, Ohio Oil Company.

The Shreveport Geological Society announces the following new officers: president, W. E. WALLACE, JR., Sohio Petroleum Company; vice-president, EDWARD W. SCOTT, Union Oil Company of California; secretary-treasurer, RICHARD T. CHAPMAN, Stanolind Oil and Gas Company.

PAUL WEAVER, Gulf Oil Corporation, Houston, Texas, spoke on "Geology of Denmark" before the June 9 noon meeting of the Houston Geological Society.

KARL A. MYGDAL, Pure Oil Company, Fort Worth, Texas, and C. D. CANTRELL, JR., Phillips Petroleum Company, Midland, Texas, presented papers on "Keystone Oil Field, Ector County, Texas," and "TXL Field, Ector County, Texas," respectively, before the May 26 annual meeting of the Tulsa Geological Society.

FRANK A. MORGAN, vice-president of the Richfield Oil Corporation, Los Angeles, California, has been in Australia and Asiatic islands, several weeks, studying petroleum possibilities.

JOHN S. REDFIELD, geologist with the Stanolind Oil and Gas Company at Tulsa, Oklahoma, for many years, was appointed assistant secretary of the Geological Society of America, New York City, effective June 1.

The Indiana-Kentucky Geological Society, Evansville, Indiana, elected the following officers on May 27: president, J. ALBERT BROWN, Sohio Petroleum Company, Owensboro, Kentucky; vice-president, GEORGE ERNEST TAYLOR, Continental Oil Company, Evansville; secretary-treasurer, P. L. KELLER, Great Lakes Carbon Company, Evansville; executive committee members: I. J. PIERCE, Phillips Petroleum Company, Evansville, and JAMES H. POTEET, Electrical Surveys, Evansville.

ROBERT B. TOTTEN, Sun Oil Company, Monroe, Louisiana, spoke before the Houston Geological Society, May 26, on the subject, "Delhi, West Delhi, and Big Creek Fields of North Louisiana."

KURT H. DE COUSSER, White Star Division, Socony-Vacuum Oil Company, Inc., Lansing, Michigan, has been appointed to serve a 3-year term on the Michigan Oil Advisory Board. He served in a similar capacity during the first 4 years following the Board's inception.

HERBERT E. WRIGHT, JR., of Brown University, has been appointed assistant professor of geomorphology in the department of geology at the University of Minnesota, Minneapolis, effective in September.

FREDERIC H. LAHEE, for 27 years chief geologist of the Sun Oil Company, has been promoted to the position of geological and research counselor for the Sun Oil Company.

FRANCIS E. HEATH has been made chief geologist of the Sun Oil Company's Dallas division.

Newly elected officers of the New Orleans Geological Society are as follows: president, D. D. UTTERBACK, Houston Oil Company of Texas; vice-president, JOSEPH B. HUDSON, Humble Oil and Refining Company; secretary-treasurer, D. NELSON ROCKWOOD, Union Producing Company.

SAM H. HOUSTON, JR., of the Humble Oil and Refining Company, Houston, Texas, died in Houston on April 19.

EDWIN BAYER BRANSON, retiring this year from formal active teaching after 37 years as professor of geology and chairman of the faculty of the geological department at the University of Missouri, was honored with his wife at a testimonial dinner held at the Daniel Boone Hotel, Columbia, Missouri, May 23. Alumni presented him with a Koda-slide master projector and a bound volume of letters of appreciation.

J. REX MCGEHEE, after several years in Calgary, Alberta, with the Shell Oil Company of Canada, is back in the geological department of the Shell Oil Company, Inc., Tulsa, Oklahoma.

J. GORDON COLE has returned from a year's service in the Bahamas as geologist and technical adviser for Nassau Oil Mining Company, Ltd. He is resuming consulting practice as a member of the firm of Cole and Lockwood, 1735 Golden Gate Avenue, Los Angeles 26, California.

JEAN JACQUES DOZY, formerly in Caracas, Venezuela, with the Caribbean Petroleum Company, may now be addressed: Bataafsche Petroleum Mij., Carel van Bylandtlaan 30, The Hague, Netherlands.

REX TOWNSEND, formerly assistant chief of the U. S. Department of State, has become a member of the firm of Hoover, Curtice, & Ruby, Inc., New York.

J. ROY MCCOY has resigned from his position with Leland Fikes, Dallas, Texas, to become head of the geological and production departments of the Anton Oil Corporation, Fort Worth.

J. B. MEANS, JR., formerly employed by the Tide Water Associated Oil Company at Jackson, Mississippi, has jointed the geological staff of Skelly Oil Company at Corpus Christi, Texas.

WILLIAM F. CALOHAN, formerly with the British-American Oil Producing Company, has opened a consulting geological office in the Esperson Building, Houston, Texas.

PAUL MONTGOMERY, formerly executive director of the Office for Natural Gas Conservation of Louisiana, has joined the consulting firm of Bates and Cornell, Lafayette, Louisiana.

ALVIN E. CHEYNEY, formerly geologist with the Skelly Oil Company, has resigned to accept a position as geologist for Sinclair Prairie Oil Company, Wichita, Kansas.

JOHN HOWARD SAMUELL has resigned his position with Lane-Wells Company as district geologist and petroleum engineer in West Texas and New Mexico and has accepted a position as petroleum engineer with the First National Bank in Dallas, Texas.

W. H. TWENHOFEL will lead the 1947 annual Tri-State Field Conference, to be held in the Silurian area of eastern Wisconsin early in October.

DURANGO, COLORADO, FIELD TRIP

A 2-day field trip covering the Animas River Valley stratigraphic section north of Durango, Colorado, was held May 24 and 25. N. Wood Bass of the Denver office of the United States Geological Survey was leader. The first day was spent between Pinkerton Hot Springs and Molas Pass, studying the section from the pre-Cambrian granite through the Ignacio quartzite (Cambrian), exposed near Pinkerton, the Elbert formation (Devonian), exposed in Cascade Canyon; (the Ordovician and Silurian are absent), the Ouray (Devonian) and Madison (Mississippian) limestones, exposed in Rockwood quarry and along the D. & R. G. W. railroad; the Molas formation (basal Pennsylvanian), exposed at Molas Lake; and the basal part of the Hermosa formation (Pennsylvanian), exposed at several places along the Million Dollar Highway (U. S. 550).

The second day was spent between Pinkerton Hot Springs and Durango, studying the Hermosa in some detail, including a section on Hermosa Creek where beds of gypsum and black shale of probable Paradox equivalent are exposed; the questionable Rico formation formerly considered to be Permian in age, but now known to be Pennsylvanian, and probably an invalid formation whose beds should be included in the Hermosa; and the lower Cutler formation of Permian age. The section from the lower Cutler to the granite is shown in detail in the *U. S. Geological Survey Preliminary Chart*, Oil and Gas Investigations, and is discussed in its accompanying text, Paleozoic Stratigraphy of Southwestern Colorado, Northwestern New Mexico, Northeastern Arizona, and Southeastern Utah, by N. W. Bass.

Because of the interest in deposits of Triassic and Jurassic age in the San Juan Basin area, the trip was extended to include these beds. The Triassic is represented by the Chinle, with questionable Shinarump present. The Jurassic deposits include a remnant of questionable Wingate, the Entrada, Todilto, and Morrison, of which the basal Morrison sand with the thin Todilto limestone and Entrada sand form the LaPlata sandstone of earlier scientific, and present-day drillers' terminology.

The trip concluded at the foot of the Dakota (Cretaceous) escarpment, with no one having enough energy left to climb it. Fifteen geologists from Durango and the San Juan Basin area participated in the trip.

J. L. BORDEN

THIRTY-THIRD ANNUAL MEETING, DENVER, APRIL 26–29, 1948

April 26–29, 1948, are the dates selected for the thirty-third annual meeting of The American Association of Petroleum Geologists, to be held in Denver, Colorado, as announced by Carroll E. Dobbin, president of the Association in Denver.

The Rocky Mountain Association of Geologists is to be the host for the occasion and it is planned that the annual meetings of the Society of Economic Paleontologists and Mineralogists and the Society of Exploration Geophysicists will be held in Denver at the same time.

T. S. Harrison, consulting geologist, has been named general chairman for arrangements and A. E. Brainerd, Continental Oil Company, is assistant general chairman.

The Shirley-Savoy Hotel is to be convention headquarters. Members are requested to cooperate with the hotels committee, Charles S. Lavington, chairman, by using the special reservation cards which will be mailed to all members in due time. Further notices will be published from time to time.

Group on Ventura field trip, following 32d annual meeting of A.A.P.G. at Los Angeles, March 24–27.
Photograph by C. C. Denny in front of Shell Oil Company employees club at Ventura field, California.

DISTINGUISHED LECTURE TOUR

MAURICE EWING, associate professor of geology, Columbia University, New York, delivered his lecture "Geophysical Investigation of Continental Borders" before the following geological groups on the dates shown.

May 1	Eastern Section—A.A.P.G.	New York, N. Y.
2	Yale University	New Haven, Conn.
8	Ohio State University	Columbus, Ohio
9	Illinois Geological Society	Mt. Vernon, Ill.
10	University of Wisconsin	Madison, Wisc.
12	University of Iowa	Iowa City, Iowa
14	Wyoming Geological Association	Casper, Wyo.
15	Tulsa Geological Society	Tulsa, Okla.
16	Ardmore Geological Society	Ardmore, Okla.
17	Fort Worth Geological Society	Fort Worth, Tex.
19	Dallas Geological Society	Dallas, Tex.
20	East Texas Geological Society	Tyler, Tex.
21	Houston Geological Society	Houston, Tex.
22	South Louisiana Geological Society	Lake Charles, La.
24	Mississippi Geological Society	Jackson, Miss.
26	Southeastern Geological Society	Tallahassee, Fla.

The Shell Union Oil Corporation, with its associated companies, has established an industrial fellowship for graduate research in Petroleum Production Engineering at the Missouri School of Mines and Metallurgy. The fellowship will be in effect during the academic year 1947–48, beginning September 1, 1947. It has been instituted to encourage graduate research in petroleum production and is open to graduate students whose training and experience are such as to qualify them for special study in petroleum production engineering. The opportunity is renewable for more than one year's tenure if warranted by circumstances and it is designed to lead to a Master or a Doctorate degree. Preferential consideration ordinarily will be given to applicants who are Doctorate candidates. To hold the fellowship will not imply that subsequent employment obligations exist either on the part of the Shell Corporation or on the part of the recipient of the grant. The Shell fellowship carries a stipend of $1200 for a year's study. In addition, the corporation will reimburse the candidate for actual tuition and academic fees and an allowance up to $300 also is established for purchase of material, equipment, and other expenses related to the research project. Applicants for this fellowship for the next academic year, beginning September 1, 1947, should write for application blanks or for any forther information to J. D. FORRESTER, chairman of the graduate committee, Missouri School of Mines and Metallurgy, Rolla, Missouri.

LESTER W. STROCK is American co-editor of the international publication for spectroscopists and spectrochemists, *Spectrochimica Acta*, published in the Vatican under the editorship of ALOIS GATTERER. Papers in English from America should be addressed to LESTER W. STROCK, 21 Madison Avenue, Saratoga Springs, New York.

The Mississippi Geological Society, Jackson, Mississippi, has elected the following officers for the 1947–48 season: president, H. L. SPYRES, Skelly Oil Company; vice-president, R. D. SPRAGUE, Sinclair-Wyoming Oil Company; secretary-treasurer, CARL F. GRUBB, The Superior Oil Company.

The Geological Forum of the Pacific Coast Section of the Association held a meeting at the General Petroleum Auditorium, 108 West 2d Street, Los Angeles, on Monday, June 16, at 7 P.M., under the chairmanship of ORRIN W. GILBERT, of the Standard Oil Company of California. The following papers were presented: "Some Aspects of Tide-

land Drilling and Development," by MILTON W. LEWIS, consultant; and "Operations in Saudi-Arabia," by MAX STEINEKE, the Arabian-American Oil Company.

SELDEN R. SELF of Houston, Texas, has resigned after completing 19 years of service in the geological department of the Amerada Petroleum Company. He was senior district geologist with the Amerada company.

MAX W. BALL, director of the Oil and Gas Division of the United States Department of the Interior, was awarded the medal of merit for distinguished achievement by the Colorado School of Mines on the occasion of the May 29 commencement. This is the fifth such medal conferred in the School's history.

W. E. WRATHER, director of the United States Geological Survey, received the honorary degree of Doctor of Engineering at the Colorado Schools of Mines commencement on May 29.

New officers of the Houston Geological Society, elected June 9: president, CHARLES H. SAMPLE, J. M. Huber Corporation; vice-president, A. F. CHILDERS, JR., Gulf Oil Corporation; secretary, HERSHAL C. FERGUSON, consulting geologist; treasurer, EUGENE L. EARL, Crown Central Petroleum Corporation. L. B. HERRING, Second National Bank, Houston, L. L. NETTLETON, Gravity Meter Exploration Company; and DONALD I. GAHAGAN, Skelly Oil Company, were elected to the advisory committee.

THOMAS HENRY HOLLAND, 78, distinguished geologist and mineralogist of Edinburgh University, Scotland, died May 17. Sir Thomas was formerly director of the Geological Survey of India.

IRA A. BRINKERHOFF has opened a consulting office at 730 Bankers Mortgage Building, Houston, Texas, for the firm of Cummins, Berger, and Pishny.

Graduate Assistantships paying from $900 for an academic year and $1200 for a calendar year, are available in the department of geology and geography of Rutgers University. Holders of these positions have free tuition. Graduate assistants will serve half-time in laboratories, grading papers, *et cetera*. Two years are normally spent in meeting the requirements for the Master's degree. Scholarships without stipend are also available for selected students. These scholarships carry remission of fees and the student has full time for research and study. One year's residence fulfills the requirement for the Master's degree. Forms for admission should be obtained and returned to the Executive Secretary of the Graduate Faculty, Rutgers University, New Brunswick, New Jersey. Applicants who have had training in geology, geology with a geographic background, or geography with a geologic background may write to the Chairman of the Department of Geology and Geography for the assistantships and to the Executive Secretary for scholarships without stipend before September 15, of the current year. Proof of admission to the Graduate School of Rutgers University must be submitted with each application.

The Instituto de Ingenieros de Minas del Peru, Lima, has elected the following officers for 1947: president, JUAN MANUEL YÁÑEZ LEÓN; 1st vice-president, MANUEL B. LLOSA; 2d vice-president, SERAFÍN LASTRES QUIÑONES; home secretary, LUIS TAPIA SALINAS; foreign secretary, CARLOS A. BOADO TAVERA.

L. L. LANCASTER, formerly with the Hunt Oil Company, is with the Seaboard Oil Company, Continental Building, Dallas, Texas.

ARNOLD F. PARR has left the Oklahoma Natural Gas Company, Tulsa, Oklahoma, to accept a position with the Pantepec Oil Company of Venezuela, at Caracas.

LOUIS CLAUDE ROARK, recently at Stanford University, has accepted a position in the Rocky Mountain region with the Phillips Petroleum Company.

FLORENCE MARIE ROBINSON has resigned from the Shell Oil Company, Inc., at Houston, to return to the University of Chicago this fall for graduate work in geology.

JAMES I. CULBERT, recently teaching at the Arizona State College, is now associate professor of geology and geography at the New Mexico College of Agriculture and Mechanic Arts, Las Cruces, New Mexico.

BURTON C. DUNN and M. J. BOREING announce the formation of a partnership of consulting petroleum geologists under the firm name of Dunn and Boreing with offices at 208 Newman Building, Durango, Colorado.

GEORGE M. STRAUGHAN recently resigned his position as geologist in charge of the geological office of the Magnolia Petroleum Company at Abilene, Texas, and has bought an interest in the J. E. Gray Drilling Company of Wichita Falls, Texas. Straughan will be in charge of the Abilene office of this company, located in the Paxton Building.

BRUCE F. LATTA, formerly associate geologist, Division of Ground Water, United States Geological Survey, and O. S. FENT, formerly geologist and test-drilling supervisor, Kansas Geological Survey, announce the firm of Latta and Fent, ground-water geologists, Salina, Kansas.

CLAUDE E. ZOBELL, professor of microbiology, at the Scripps Institution of Oceanography, La Jolla, California, has been awarded a special fellowship by the Rockefeller Foundation, which provides for a year of travel and study in European research laboratories. After discharging his responsibilities as vice-president of the Fourth International Congress for Microbiology in Copenhagen, ZoBell will continue his studies on the origin of oil, with particular reference to the effect of pressure on the transfer of hydrogen in European laboratories where similar work is being done.

In order to encourage research pertinent to the industrial activities of the Wichita area, the University of Wichita Foundation for Industrial Research is offering two graduate fellowships, leading to the Master's degree at the University of Wichita for the academic year 1947–48. One will be granted in chemistry, and the other in petroleum geology. Each carries a stipend of $1000 for the degree, plus tuition and fees. The recipient of the fellowship in petroleum geology will be required to assist in the elementary courses in geology quarter-time, for which he will be paid $187.50 per semester in addition. These fellowships will be awarded on the basis of merit to graduates of accredited colleges or universities. Further details may be secured from Hugo Wall, chairman of the committee on scholarships and student aid, University of Wichita, Wichita 6, Kansas.

Fifty societies will meet with 15 sections of the American Association for the Advancement of Science at its 114th meeting, to be held in Chicago, December 26–31, 1947. Section E (Geology and Geography) will meet on December 26 and 27. The December 26 sessions will center on a symposium entitled "Ground Water Geology and Engineering," organized by E. J. SCHAEFER, United States Geological Survey, Columbus, Ohio. J. MARVIN WELLER, University of Chicago, is arranging for a symposium on "Mississippian," to be presented on the morning of December 27, and in the afternoon Section E will meet jointly with Section D to discuss the "Origin of the Solar System." GEORGE W. WHITE, secretary of Section E, is developing the program with the assistance of M. P. BILLINGS, chairman.

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A symposium conducted by the Research Committee of The American Association of Petroleum Geologists, A. I. Levorsen, chairman. Papers read at the Twenty-sixth Annual Meeting of the Association, at Houston, Texas, April 1, 1941, and reprinted from the Association *Bulletin*, August, 1941.

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Cities Service Oil Company, Box 350

Meetings: Luncheon 1st and 3d Wednesdays of each month, 12:00 noon, Herring Hotel. Special night meetings by announcement.

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Meetings: Monthly luncheons by announcement. Special night meetings by announcement.

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Secretary-Treasurer - - - - Walter E. Long
Magnolia Petroleum Company
Box 780

Luncheons: Each week, Monday noon, Blackstone Hotel.

Evening meetings and programs will be announced. Visiting geologists and friends are welcome.

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FORT WORTH, TEXAS

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Vice-President - - - - - - R. H. Schweers
The Texas Company, Box 1720
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Pure Oil Company
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Meetings: Luncheon at noon, Hotel Texas, first and third Mondays of each month. Visiting geologists and friends are invited and welcome at all meetings.

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Sinclair Prairie Oil Company
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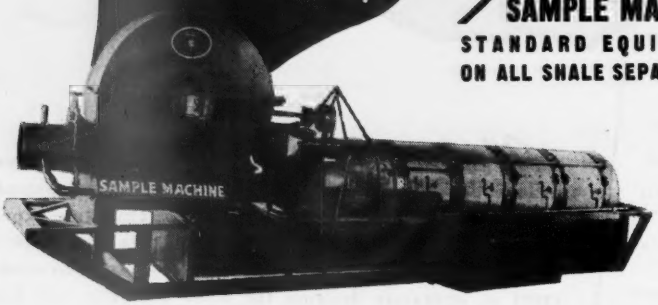

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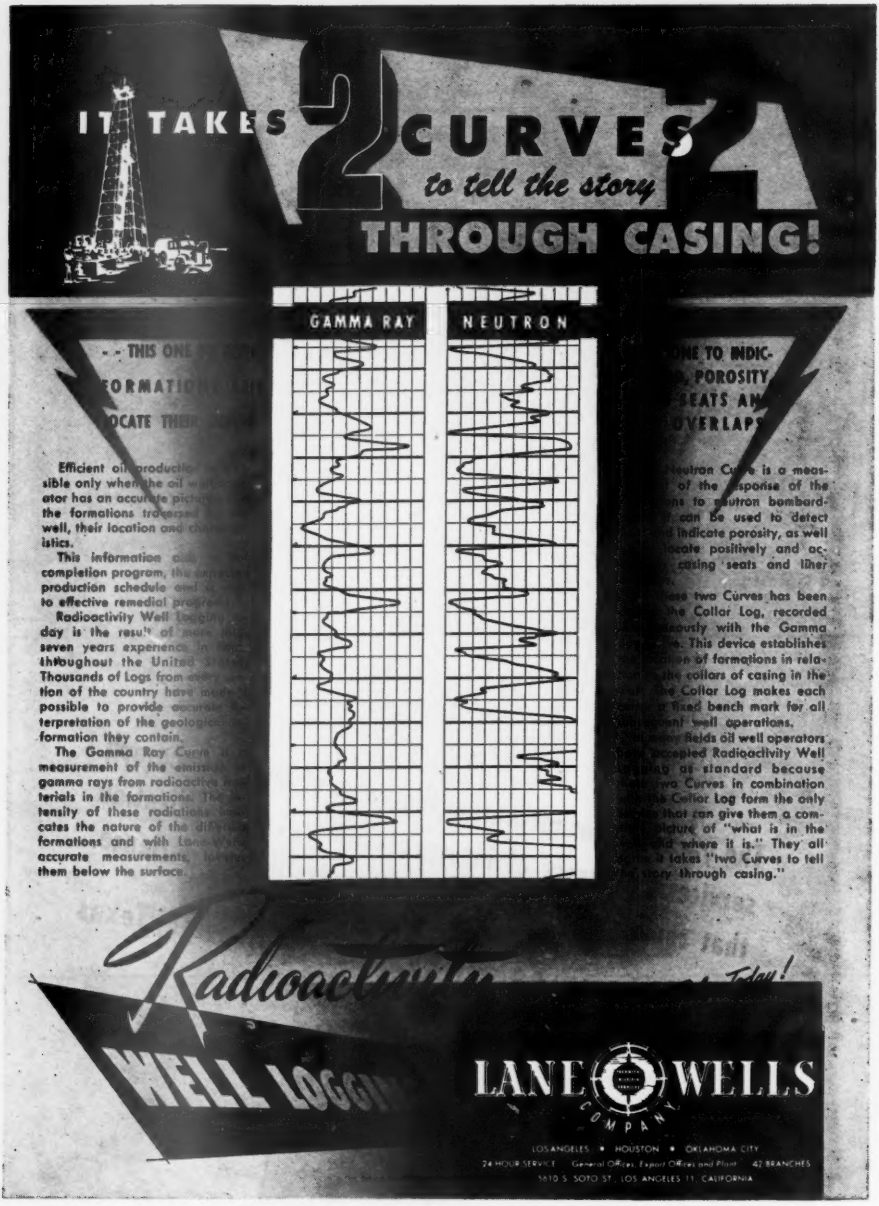
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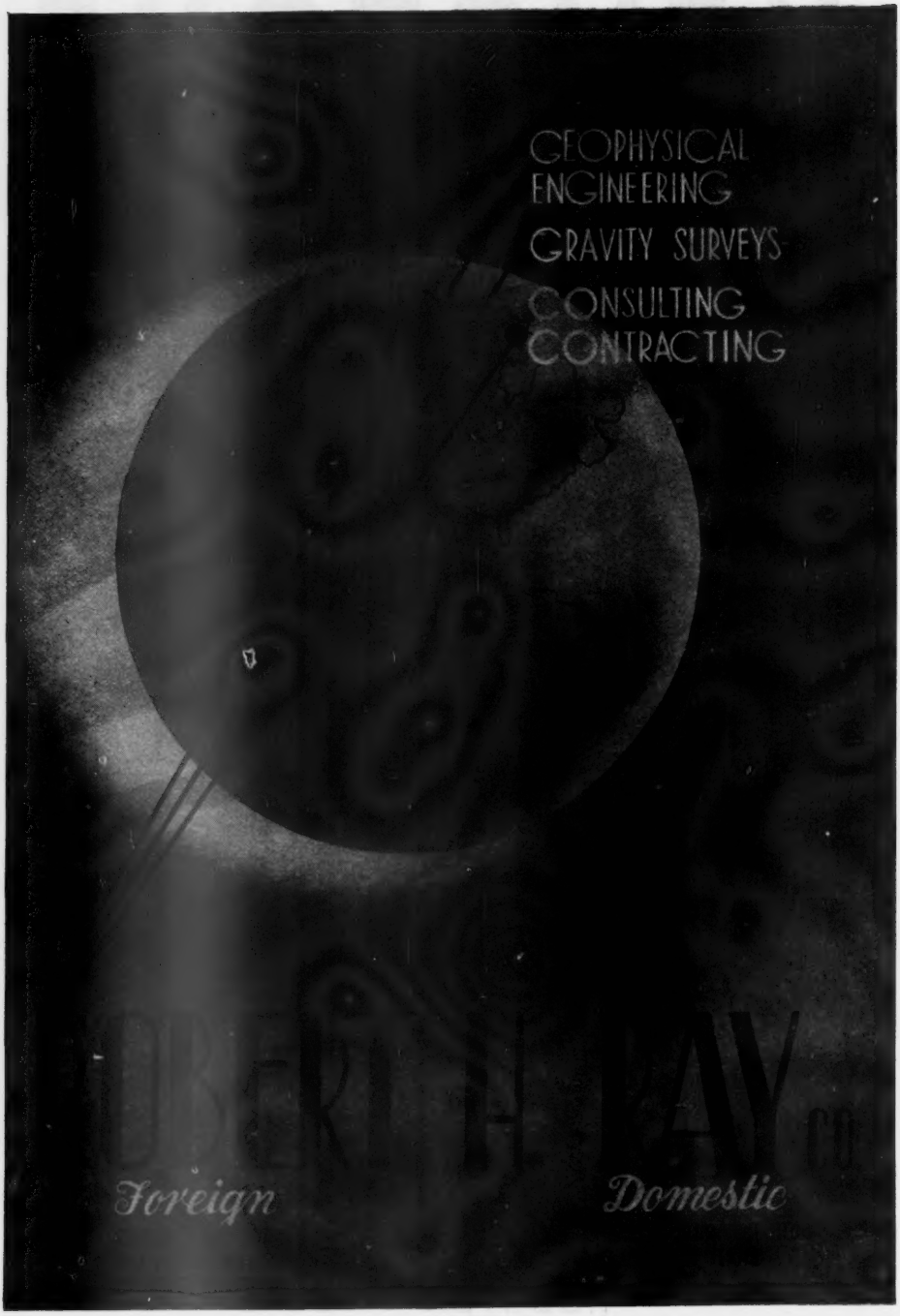
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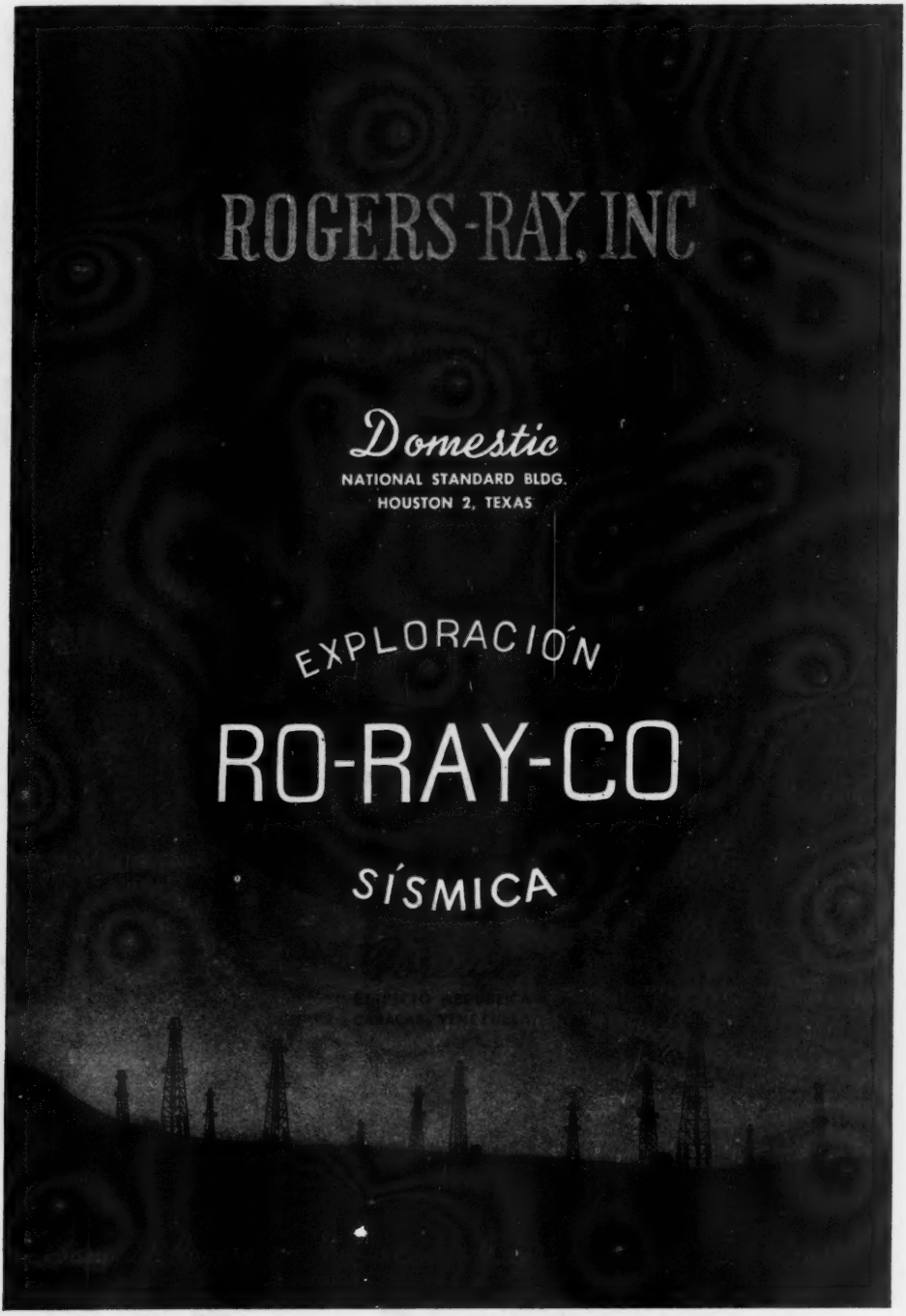
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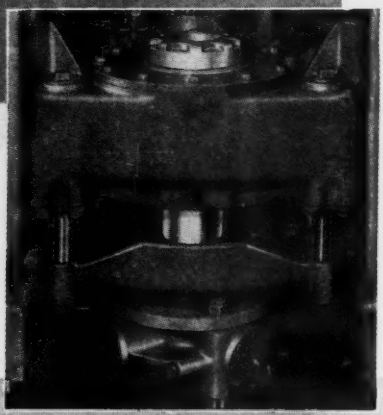

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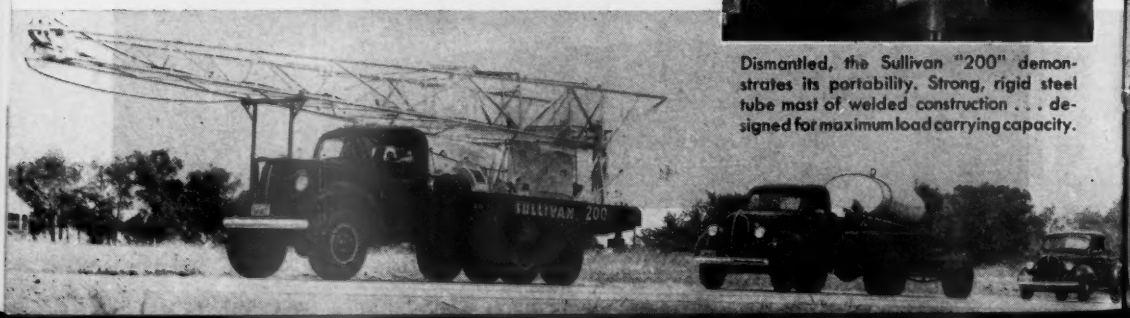

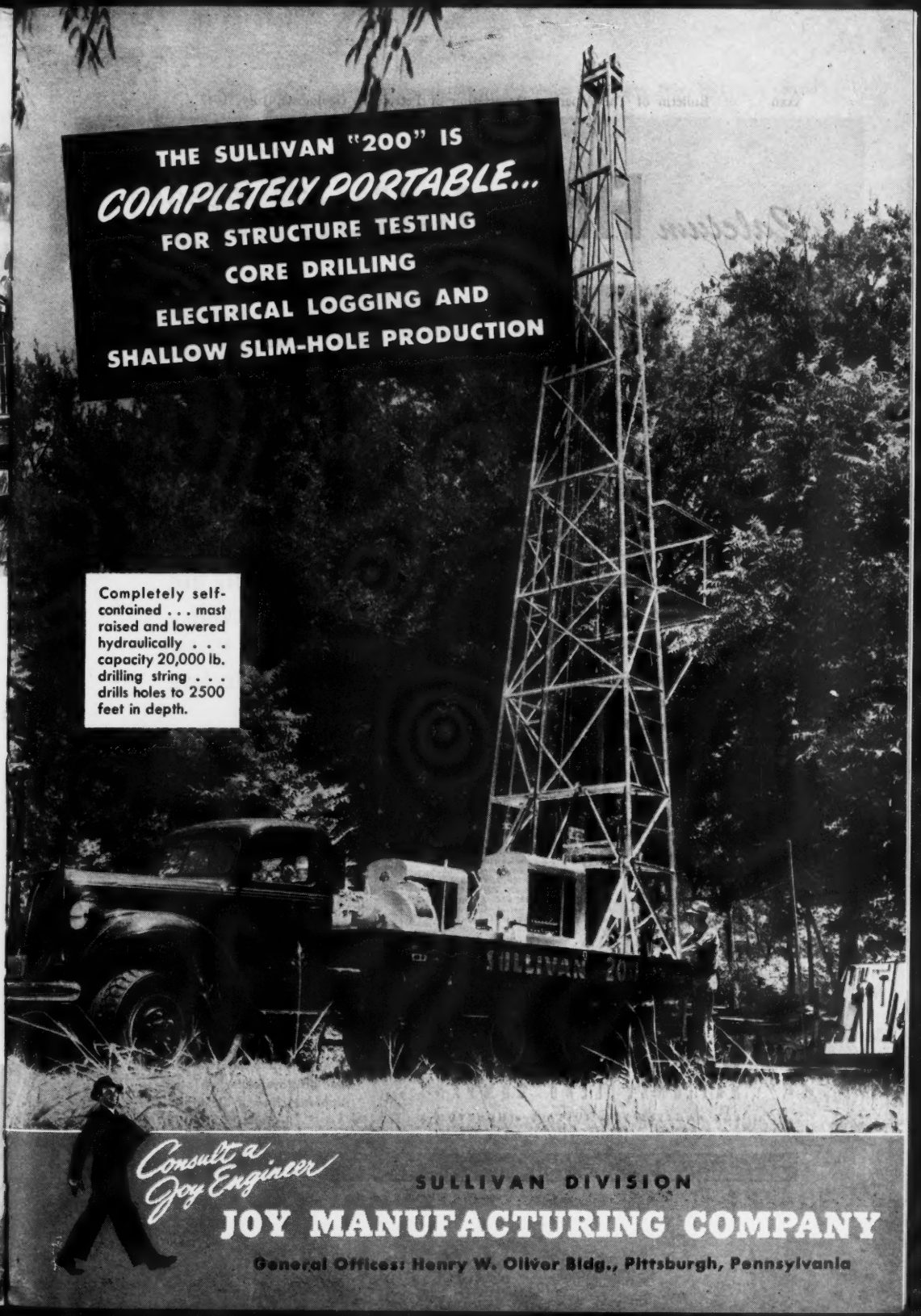
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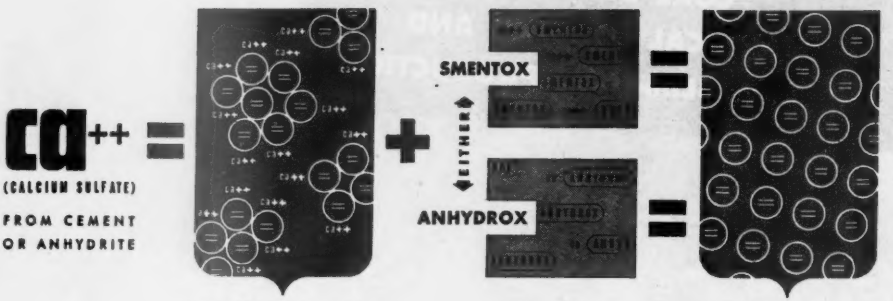

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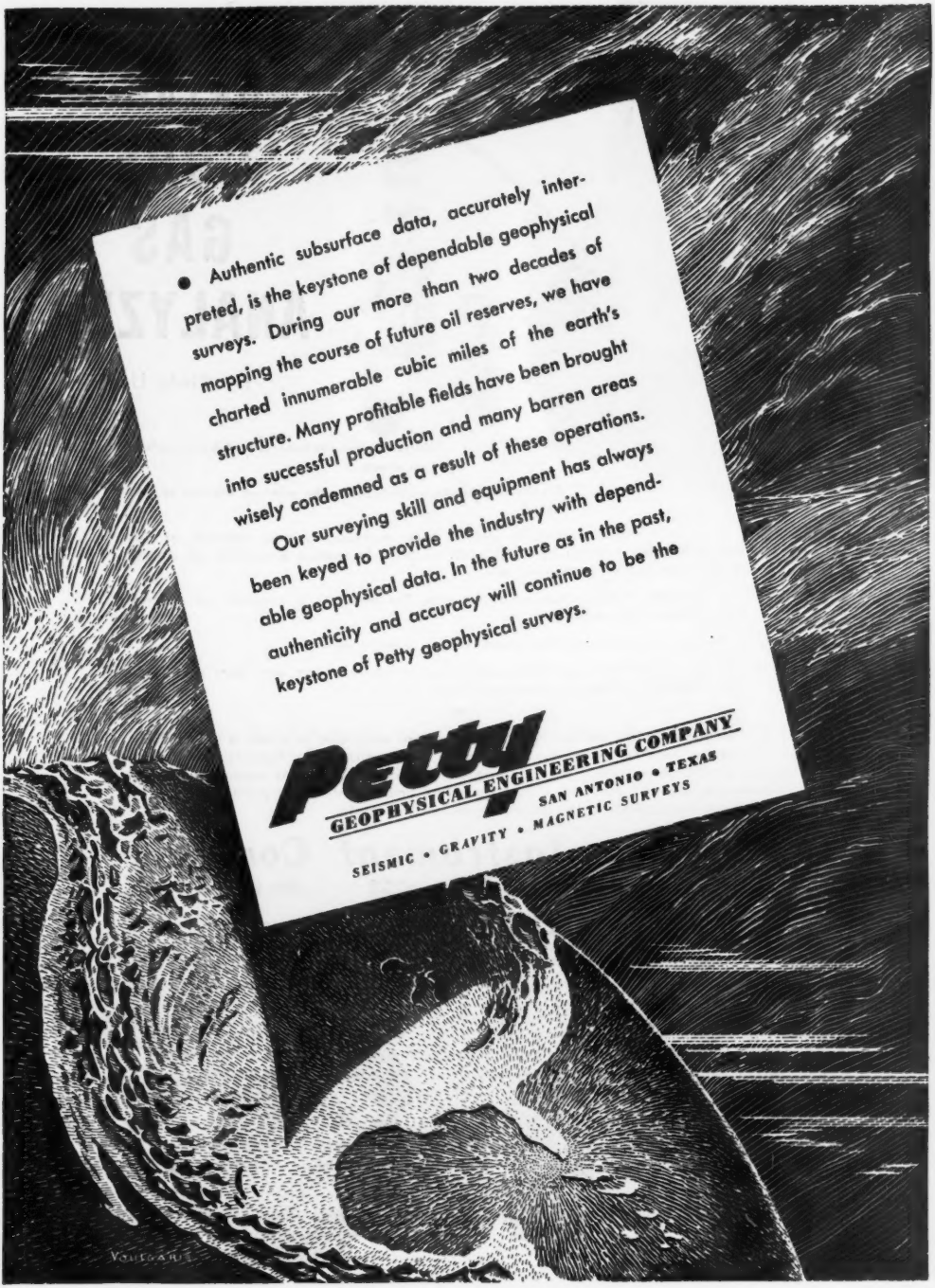
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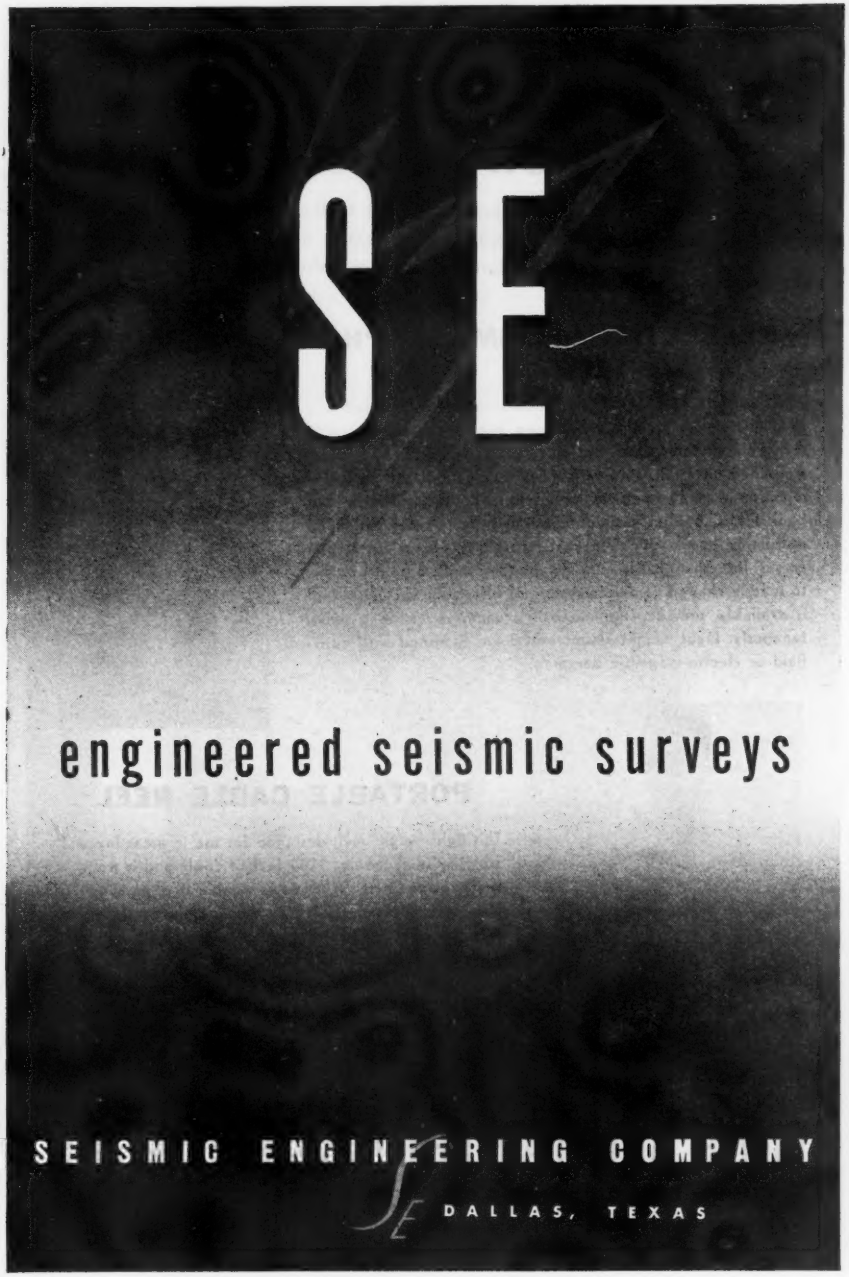
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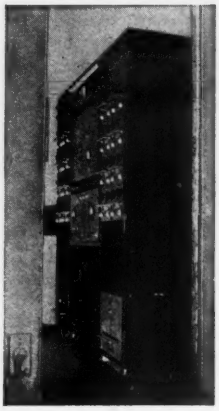

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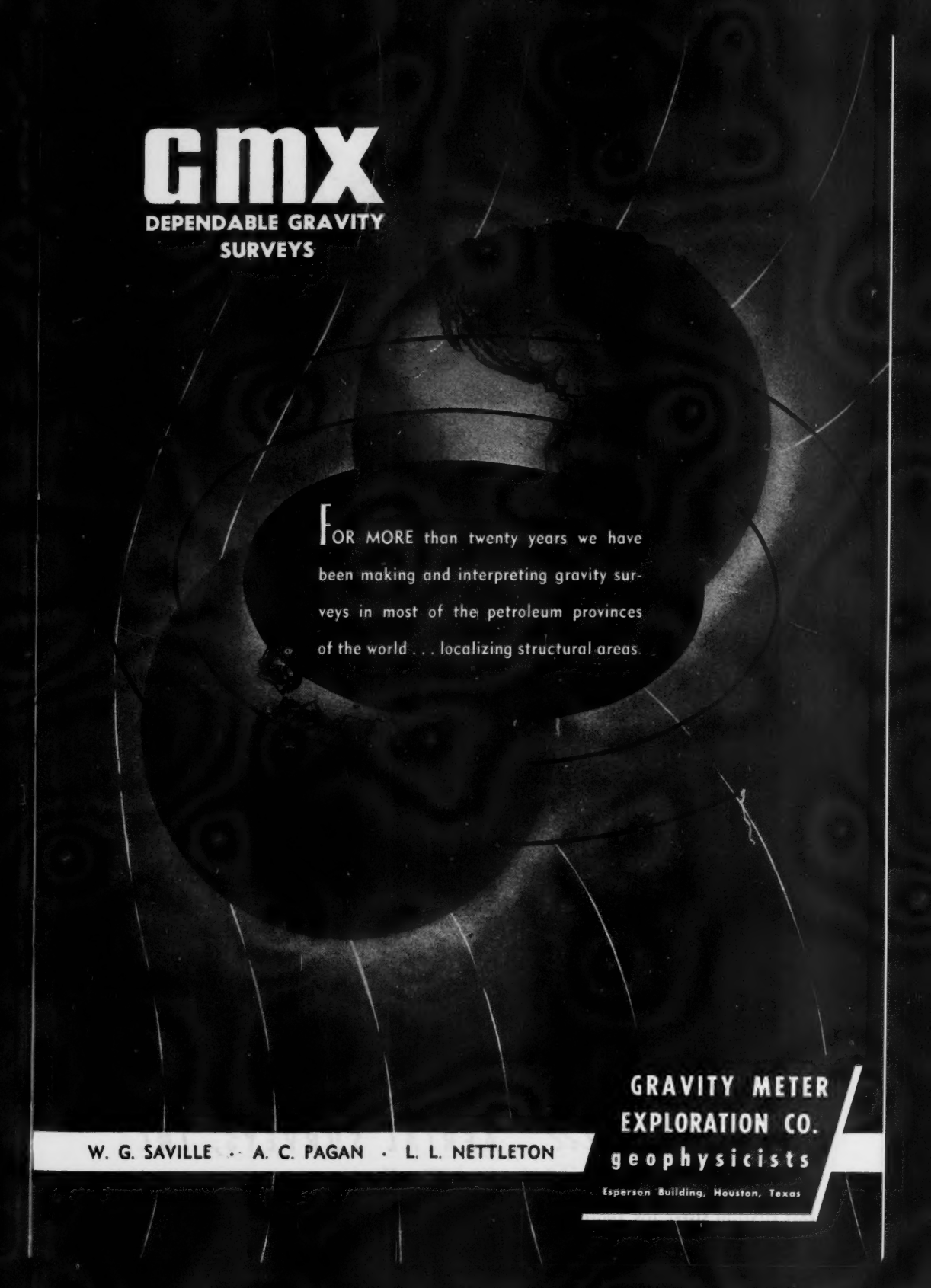

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It is based on information compiled from the literature and from a canvass of leading geologists, geophysicists, and petroleum engineers in the United States and foreign countries. Covered are important events of the year, advances in petroleum geology and contributory fields, including developments in the training of geologists and geophysicists, progress in the developments in geophysics and geochemistry, developments in petroleum engineering, aerial photographs, new and improved techniques, world exploration and development, production and reserves, trends in petroleum geology and geophysics, and the future of the petroleum industry.

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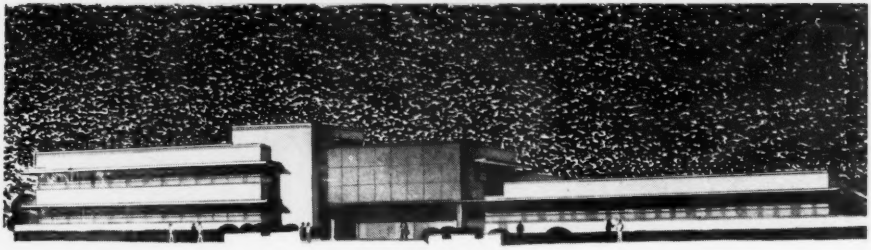

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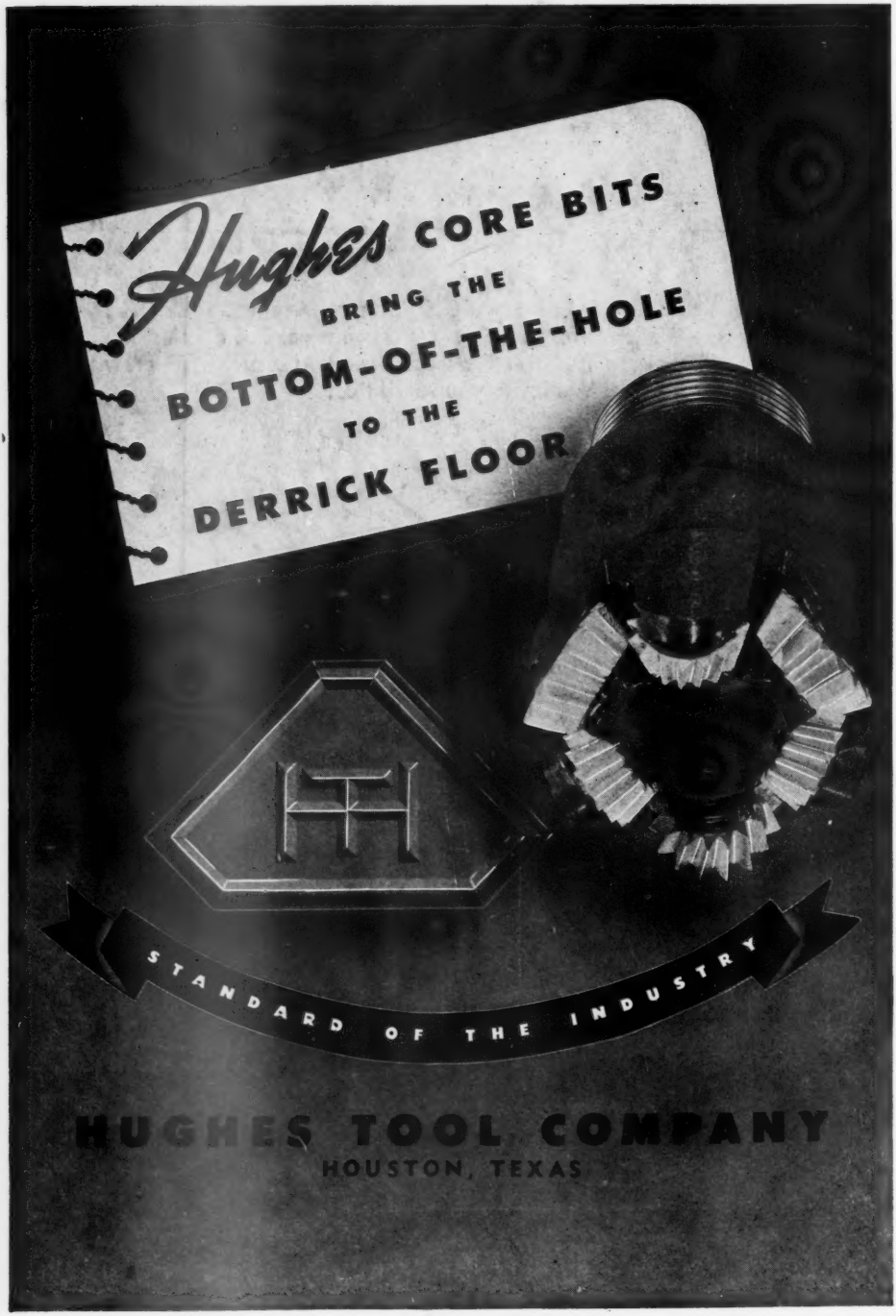
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Volume 31 AUGUST, 1947 Number 8

BULLETIN
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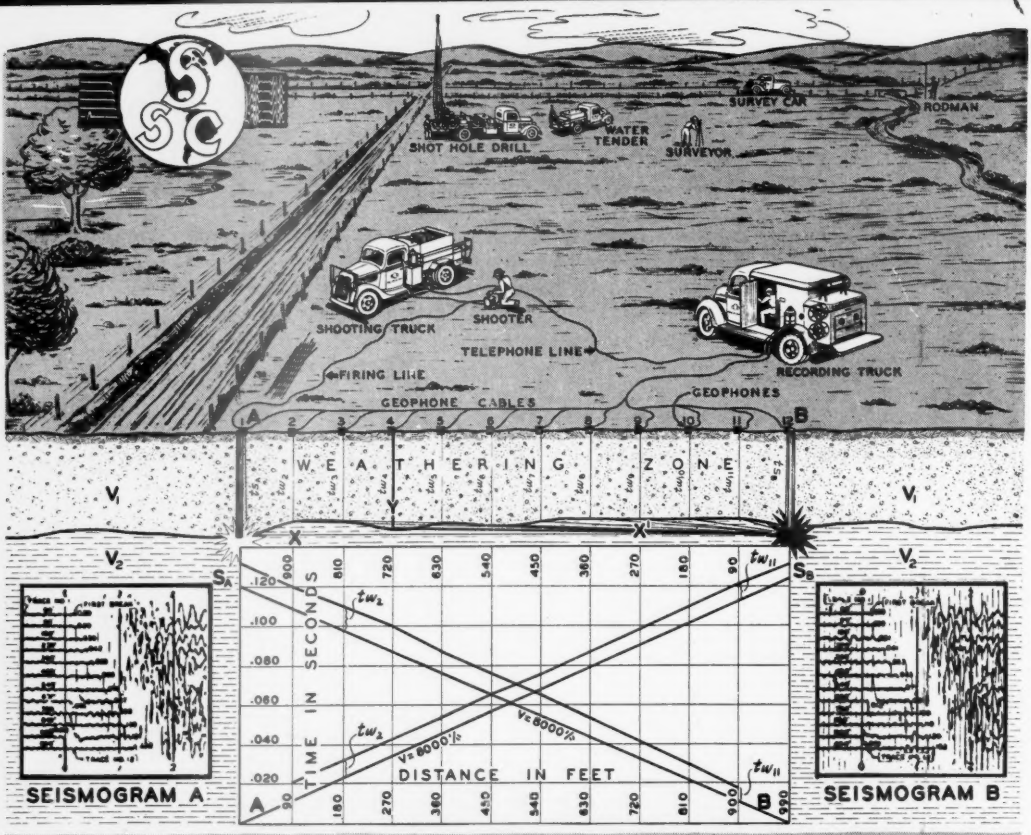

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